Restoration Opportunities at Tributary Confluences:

Critical Habitat Assessment of the Big Chico Creek/Mud Creek/Sacramento River Confluence Area

A report to:
The Nature Conservancy,
Sacramento River Project[1]

By:
Eric M. Ginney[2]
Bidwell Environmental Institute,
California State University, Chico

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[1]Please direct correspondence to:
TNC, Sac. River Project
Attn: D. Peterson
505 Main Street,
Chico CA 95928
dpeterson@tnc.org

[2]Bidwell Environmental Institute
CSU, Chico, Chico, CA
95929-0555
eginney@csuchico.edu

Cover: An abstract view of the Sacramento River, looking upstream. Big Chico Creek enters from the east, in the lower portion of the image. Photograph and image manipulation by the author.

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Section I: Study Purpose, Methods, and Objectives

Purpose

This project evaluates the current and historic physical and ecological conditions of the land surrounding the confluences of Big Chico and Mud Creeks with the Sacramento River (the study area). The goal of this project is to provide a conceptual analysis of alternative restoration options within the context of the current and potential ecological conditions, local infrastructure, and the willing participation of landowners in conservation programs (acquisition & restoration).

A central focus of this report is the 40-acre Singh parcel (the site), located adjacent to the Bidwell-Sacramento River State Park. The Nature Conservancy (TNC) has an option to purchase the Singh parcel with the intention of subsequent deed of title to the State of California Department of Parks and Recreation. Several other landowners are also considering participating in conservation programs. Annexation of this or other parcels into the Bidwell-Sacramento River State Park would provide the opportunity to restore and preserve additional critical habitat for threatened and endangered species along the Sacramento River. Further, such activities are consistent with the goals and actions of the Upper Sacramento River Fisheries and Riparian Habitat Management Plan (California Resources Agency, 1989) and the Sacramento River Conservation Area (SRCA) handbook, updated in 2001(California Resources Agency, 2001).

The goal of the United States Fish and Wildlife Service's (USFWS) Anadromous Fish Restoration Program (AFRP), which provided the funding for this project, is to "Develop within three years of enactment and implement a program which makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991." (USFWS, 2001). This is to be realized through the involvement of partners in the implementation and evaluation of restoration actions, and improving habitat for all life stages of anadromous fish through provision of flows of suitable quality, quantity, and timing, and improved physical habitat (*ibid*). The efforts put forth in this project support such efforts, and play an important role in the long-term success of fisheries restoration efforts (Icanberry, *personal communicatio*n; 2001).

Methods and Objectives

Specifically, this project assesses the quality of the existing habitat on the site, identifies critical habitat, and evaluates the potential for protecting and restoring specific habitat types for species of special concern within the study area. The Nature Conservancy undertook this project with an eye toward preserving and restoring physical and ecological processes and followed the principles developed by the SB 1086/SRCA process. "Conservation by Design: A Framework for Mission Success" (systems, stresses, sources, strategies, success), a strategy document developed by The Nature Conservancy, also provided a framework for analysis of the site (TNC, 2001a).

The initial phase of the project involved research and analysis of historic conditions done through analysis of maps, photographs, and written accounts. Soils information was also used to corroborate inferences on vegetation gained from historic accounts and models of landscape ecology.

This initial phase continued with site reconnaissance and an assessment of baseline conditions at the project site. Individuals with expertise in various natural resource disciplines were consulted during this phase of the project and their specialties are outlined in Table 1.

Name	Agency	Specialty
Koll Buer	DWR	Geology and Geomorphology
Stacy Cepello	DWR	SRCA issues and riparian restoration
Woody Elliot	DPR	Information on neighboring "Peterson Addition" parcel
Suzanne Gibbs	BCCWA	Big Chico Creek issues and restoration potential
Adam Henderson	DWR	GIS and aerial photographs
Paul Maslin	CSUC	Fisheries and riparian restoration
John Merz	SRPT	Issues regarding restoration planning
George Nicholas	Land Manager	Issues regarding farming in the area
John Nock	Neighboring Landowner	Issues regarding farming in the area
Bruce Ross	DWR	Geology and Geomorphology
Stacy Small	PRBO	Riparian Bird Species

Table 1: Experts with individual areas of expertise consulted during this study

Vertical and oblique aerial photography, observations from light aircraft, information from a geographical information system (GIS), and on-the-ground observations were utilized to assess current conditions and provide information and imagery for discussion. Stakeholders were presented a synopsis of preliminary findings following the reconnaissance and assessment period. Landowners and land managers from the area provided a good deal of knowledge related to issues such as flooding and land use history. The presentation stressed interactive discourse in an attempt to gain additional information as well as input and perspectives on restoration and associated activities. Finally, feedback from the stakeholder meeting was then synthesized into this report, which details preliminary restoration strategies and perspective land management activities.

Section II: Tributary Confluences: Restoration Opportunities Waiting to Happen

Ecological Importance of Tributary Confluences and Adjacent Floodplain

The Nature Conservancy (TNC) has determined that the flood-prone lands associated with tributary confluences on the main-stem Sacramento River are significant for their biological and ecological values (TNC, 2000). Such habitats can include high quality riparian forest, valley oak riparian woodlands, sloughs, backwaters, and important rearing habitat for native fish species, both resident and anadromous. These tributary confluences are the gateways of the migratory routes for anadromous and resident fish species alike, and the inundated floodplains surrounding these confluence areas act as a sanctuary for juvenile fish during high flow events on the river (Maslin, *et al.*, 1999). These confluence areas also function as major sources of nutrients, woody debris, and other organic materials (Vannote, *et al.*, 1980). The use of inundated floodplains as rearing habitat for juvenile fish has received increased attention of late and for good reason--growth rates and health of salmonids appear to be increased as compared to similar fish in the mainstem of the river (Sommer *et al*., 2001; Sommer *et al*., 2000).

While tributary confluence areas have not been the primary focus of much research on the Sacramento River, the subject has been explored on rivers elsewhere. Much of this research has been theoretical, and empirical studies have mostly focused on investigating hydraulics, chiefly on braided river systems, and in mountain and piedmont systems (Best, 1987; Ashmore and Parker, 1983; Roy and Bergeron, 1990; Rice, 1998). However, from this limited empirical and theoretical research coupled with other work examining the ecological roles of stream confluences on rivers outside California, the role and importance of these river features can be briefly illustrated.

The role of confluence areas on the physical and ecological processes on the Sacramento River is emerging as an increasingly important aspect when placed in perspective with what is perhaps the most obvious value—habitat. In a heavily regulated river system like the Sacramento, it is easy to forget or diminish the role of tributaries as sources of stream flow, particularly intermittent streams. Relative to the regulated main-stem river, many of these tributaries are unregulated, and as such, maintain “natural” levels of turbidity and temperature as well as a naturalized hydrograph. These factors have important implications for natural processes.

On a landscape level, confluence areas are the link between the riverine environment and the upland areas that drain to the river—the most important turn on the migratory road map for certain aquatic and avian species. If confluences are ecologically disconnected from the river because of the removal of riparian vegetation, emplacement of bank revetment, channelization, or through water diversions—with subsequent reductions in flow and increases in temperature—they are separated from the river-upland continuum.

Osborn and Wiley (1992) note the importance of the spatial pattern of tributaries in a drainage area on aquatic community organization. These researchers found higher species diversity occurred when lower-order tributaries connected to higher-order main stem stream segments, when compared to the connection of two low-order streams. Tributary inputs which result in a coarsening of the mainstem substrate downstream of the confluence illicit community responses that include an increase in species richness and an increased abundance of aquatic taxa that prefer coarse substrate (Rice, Greenwood, and Joyce, 2001a). Additionally, the aforementioned tributary influx of nutrients, coarse and fine particulate organic matter, and invertebrate drift plays into the concept of the "river continuum" (Vannote et al., 1980). The "river continuum" concept states that biological characteristics of structure and function in stream communities are adapted to conform to the mean state of the physical system. As physical conditions change from the headwaters downstream, a gradient (or continuum, similar to that described by Leopold and Wolman, 1957) of biological conditions emerges. The biological system along the length of the stream reacts with a series of responses due to changes in this equilibrium. These changes can be termed a "continuum of biotic adjustments" (Vannote et al., 1980). Tributary inputs can "reset" these longitudinal trends either forward or aft on the nominal downstream gradient (Minshall *et al*., 1985) and can even result in a shift from autotrophic to heterotrophic for a section of a larger stream below of a tributary (Vannote, *et al*., 1980). Perry and Schaefer (1987) even suggest that due to tributaries, river benthos is more a river "discontinuum" rather than the continuum suggested by Vannote, *et al*. (1980).

Confluence areas also play an important role in the hydrologic, hydraulic, and sediment transport processes of river ecosystems (Poff *et al.*, 1997; Large and Petts, 1996). Due to Shasta Dam upstream, the sole sources of bed load sediment in the Sacramento River system below the dam are the tributaries (G. M. Kondolf, *personal communication*, 2001), and as a result, tributaries now maintain an even more critical role in the balancing of the river's sediment budget. Rice, Greenwood, and Joyce (2001b) note that while "dry" sources of sediment, termed "lateral sediment sources (LSSs)", can bring significant sources of sediment to the river through points of significant bank erosion, or in steeper catchments, landslides, on the regulated Sacramento River, tributaries appear to be the most important source of coarse sediment in the post-dam sediment regime.

The hydraulic interaction of the two convergent flows (tributary and mainstem) typically acts to create a scour hole of significant depth, as well as alter channel slope and planform, channel dimensions, and change sediment size and sorting processes (Rice, Greenwood, and Joyce, 2001b; Paola, 1997). As the hydrograph recedes, sediment may be deposited at the tributary confluence due to discordant flows between the mainstem and tributary. These sediment deposits at the mouths of tributary streams also act as sources and sinks of sediment for the river itself during lateral migration. And, as is the case of Big Chico Creek, such deposition at tributary confluences can actually build important riparian forest and low-velocity backwater habitat (see Figures 1a and 1b). Gaudet and Roy (1995) note that river managers can improve the design or maintenance of channel systems in terms of effluent or contaminant dispersal, as the depth differential between the two converging flows can be used to increase or decrease the intensity of mixing. Such a managed river scenario could also be used to create managed scour to protect pump intakes, and other infrastructure.

Tributary confluences are also important from the perspective of the preservation or restoration of river processes. Large and Petts (1996) found in their research that after over 200 years of intense regulation on the River Trent, the only remnant unstable and dynamic areas of the river were located at tributary confluences. This instability is likely due to the dynamic nature of tributary confluences hampering attempts to channelize and control the river in this reach through avulsions and channel migration. As such, despite the degraded nature of the river, these confluence areas retained the greatest degree of natural sedimentary structure, sediment fluxes, and vegetation communities. In light of this, the authors recommend that restoration efforts be focused in 'islands' at tributary confluences, with these "beads" of habitat being the foundation for the later linking of this "string of beads" (Large and Petts, 1992). Due to their dynamic physical and ecological processes, an emphasis on confluence areas as priorities for restoration seems merited and perhaps should be advocated.

Importance of Sacramento River Confluence Areas in Collaborative Restoration Efforts

Main-stem tributary confluences represent an important link between restoration efforts at the tributary-watershed scale and the basin scale. In 1986, the California State Legislature passed Senate Bill 1086 which called for the development of a management plan for the Sacramento River and its tributaries to protect, restore, and enhance both fisheries and riparian habitat. In 1998, the Sacramento River Conservation Area (SRCA) handbook was completed and the participating agencies and stakeholders signed a "Memorandum of Agreement Regarding the Sacramento River Conservation Area (MOA)." This MOA endorsed the formation of the non-profit SRCA, established in 1998 to develop and implement collaborative habitat management and restoration actions along the Sacramento River and its tributaries. One of the goals of the SRCA is to preserve the remaining riparian habitat and reestablish a continuous riparian ecosystem along the Sacramento River between Chico and Red Bluff. This includes the determination of the "Inner River Zone Guideline" (IRZG), an area of variable width near the main channel of the river where habitat protection would be a priority and the river's physical processes would be allowed to function (California Resources Agency, 2000). All restoration and management actions in the SRCA are on a voluntary basis. Landowners within the SRCA and IRZG boundaries are eligible to participate in the program, but are not required to do so.

As a simple function of hydraulics, tributary confluence areas are, by their very nature, susceptible to increased flooding hazard, given the intersection of two streams and a finite amount of channel area. Flooding and the associated channel movement in these confluence areas has created soil of excellent quality and has led to agricultural operations, typically orchards. Operations in these locations have, by necessity, either been designed in an attempt to minimize the abuses of frequent flooding (i.e. the private berm on the right bank of Mud Creek), or accepted the increased costs of production due to debris removal and disease as a result of frequent inundation as a part of their operations, or both (Nock, *personal communication*, August 21, 2001; Nicholas, *personal communication*, August 21, 2001). Not all areas near tributary confluences share these farming difficulties. Several landowners in the area of the study site commented that production costs on a per acre basis can be much higher in sites such as those described above, when related to comparable land at higher elevations or greater distances from the river. In such cases, sale of this land and subsequent restoration to riparian habitat may be the most economically prudent plan for landowners in these areas. This is a good example of how a willing seller can take advantage of opportunities through the SRCA or one of that organization's cooperating partners to purchase and restore flood-prone lands along the river.

Most Sacramento River tributaries at this time have their own conservation organizations that are working on issues similar to that of the S.B. 1086/SRCA process. Because of this, tributary confluences present an opportunity for the SRCA and its cooperators to collaborate with what are regionally known as "watershed groups." This can be undertaken through integration of goals and objectives, the formation of joint partnerships for funding, lending endorsements for one another, and interacting via information sharing and networking.

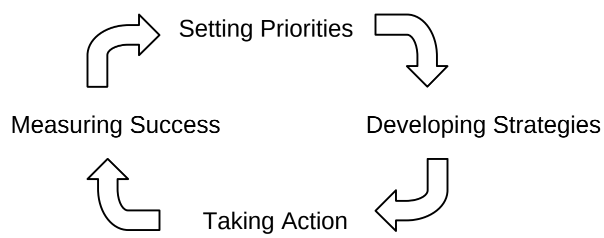
An important physical-process linkage between tributary-scale restoration efforts and efforts at the basin level is that of increased runoff from urbanized areas. Increased runoff from urbanized watersheds has been identified an increasing problem in the United States (U.S. Environmental Protection Agency [EPA], 1998). The most recent data available from the National Water Quality Inventory (1998), reports that runoff from urban areas is the second leading source of impairments to surveyed estuaries and the third largest source of water quality impairments to surveyed rivers and lakes. The EPA also recognizes NPS pollution to include "…adverse changes to the vegetation, shape, and flow of streams and other aquatic systems," what they term "hydromodification" (EPA, 1998). Existing reports and case studies provide strong evidence that urbanization negatively affects streams and results in water quality problems such as loss of habitat, increased temperatures, sedimentation, and loss of fish populations (EPA, 2001). "However, relatively few case studies have assembled detailed quantitative information to document these phenomena. This is due, in part, to (1) the heavy reliance on engineered approaches to runoff management that can transfer hydrologic impacts (e.g., habitat loss, flooding, channel widening, and erosion) to downstream areas through the construction of paved channels, storm water pipes, and bank stabilization (e.g., riprap, cutbacks, plantings, bulkheads) and (2) the difficulty and high costs associated with long-term watershed monitoring. Furthermore, the installation of drainage structures, such as pipes and concrete channels, is the final step in removing urban streams from the landscape. Classically, many of these activities have resulted in urban streams being "written off" as virtually nonexistent; therefore, the resulting impacts on water quality and habitats are being ignored" (EPA, 2001).

Human populations in Sacramento River tributary watersheds have increased significantly in the last decade and are predicted to increase at still greater rates in the coming decade (Great Valley Center, 2001a & 2001b). Given the increases in urban runoff, the related impacts to aquatic systems, and the associated pollutants transported by them, tributary confluences may perhaps be the most appropriate locations to begin addressing system-wide impacts and begin restoration. For example, confluence areas may be a location where flood-peak attenuation through floodplain restoration and storage may be a viable option. Floodplain restoration could simultaneously provide benefits to aquatic species by creating additional natural habitat. Based on the known land use impacts created by increased human habitation, it seems prudent for increased communication between main-stem river restoration workers and those individuals and groups working on the tributaries.

Conservation By Design

Restoration planning and activities along the Sacramento River are being conducted in a systematic fashion. The formation of the Sacramento River Conservation Area (SRCA) is the result of over 15 years of collaborative work between riverine landowners, conservation groups, local governments and government agencies, NGOs, and other interested parties. The Nature Conservancy (TNC) Sacramento River Project has been a major participant in this effort, tailoring their conservation efforts (such as sub-reach planning and site-specific management and planning, explained in the following section) to support the goals and principles of the SRCA.

At an international level, TNC has established what they term a "Conservation Approach" to attaining their goal of preserving functional landscapes around the globe. That approach is outlined below, beginning at the top of the circle:



A critical step in this approach is the development of strategies. TNC has adopted the "5-S Framework" for site conservation planning strategies. The approach focuses on the following components:

1) Systems: the key conservation targets and supporting ecological processes;
2) Stresses: the most serious types of destruction or degradation affecting the conservation targets or ecological processes;
3) Sources of stress: the causes or agents of destruction or degradation;
4) Strategies: the full array of actions necessary to abate the threats or enhance the viability of the conservation targets;
5) Success measures: the monitoring process for assessing progress in abating threats and improving the biodiversity health of a conservation area.

This report addresses the first three "Ss" directly, and provides some specific alternatives for the fourth "S," Strategies. On the Sacramento River, an on-going strategy utilized by TNC is sub-reach planning. TNC's sub-reach planning focuses on protection and restoration of riparian and aquatic habitats at a larger river scale (~20 river miles) and serves as a bridge between restoring individual parcels and the development of the Sacramento River Conservation Area. Inset within sub-reach planning is site-specific management and planning, which addresses potential changes in hydrology and geomorphology, local economic impacts, and other issues associated with riparian protection and restoration work on a parcel-by-parcel basis. All planning efforts include input from local landowners, public agencies, and other interested parties. The final "S" (success measures/monitoring) is incorporated after action is taken (see loop in the Conservation Approach, above).

Site-Specific Planning

An important aspect of TNC's restoration activities on the Sacramento River is how their approach to conservation interfaces with the goals, principles, and recommended actions of the Sacramento River Conservation Area (SRCA). The following is excerpted and paraphrased from the SB 1086 Sacramento River Conservation Area Handbook, updated in 2001:

SB 1086 Riparian Habitat Management Program

Goal	Preserve remaining riparian habitat and reestablish a continuous riparian ecosystem along the Sacramento River between Redding and Chico, and reestablish riparian vegetation along the river from Chico to Verona.
Principles	Use an ecosystem approach that contributes to the recovery of threatened and endangered species and is sustainable by natural processes
	Use the most effective and least environmentally damaging bank protection technique to maintain a limited meander, where appropriate
	Operates within the parameters of local, state and federal flood control and bank protection programs
	Participation by private landowners is voluntary; never mandatory
	Give full consideration to landowner, public, and local government concerns
	Accurate and accessible information/education is essential to sound resource management

The Sacramento River Conservation Area Handbook also proposes a list of recommended actions including agency coordination, permitting, education and outreach, and other issues, but perhaps the most crucial element pertaining to restoration of confluence areas is the SRCA's desire to "Develop Site-Specific Plans and Contracts."

Site-specific management plans are to be used as the building blocks of the Sacramento River Conservation Area, particularly in areas falling within the inner river zone guideline. Site-specific plans outline current conditions and assess existing potential to protect and restore habitats and river processes. Consideration is to be given to ecological processes (flooding and channel migration), habitats (riparian forests, sloughs, gravel bars, and shaded riverine aquatic), and identified locations of sensitive sites (bank swallow colonies, yellow-billed cuckoo nests, and winter run Chinook salmon redds). In addition, current land use, ownership, and development infrastructure is important in determining realistic restoration projects.

Site-specific management plans are intended to address issues that could affect neighboring landowners and to propose ideas for successful restoration of the site. A site-specific plan should describe program eligibility and where proposed management actions would rank in terms of the overall riparian restoration strategy. The highest priority projects are those that preserve intact process and are cost effective. All plans are to be in compliance with the guiding principals of the SB 1086 Riparian Habitat Management Program. The following actions could be taken as part of a site-specific management plan:

- conservation easements
- set-aside agreements
- bank protection
- land acquisition from willing sellers
- landowner protections
- floodplain management strategies

The above actions would be carried out through contractual agreements on individual properties that would contain enforcement provisions if either party were to violate the contract.

The Nature Conservancy Sacramento River project supports the goal and principles of the SRCA and will work toward the Conservation Area's goal through cooperative actions in areas like the Big Chico/Mud Creek confluence area.

Section III: Critical Habitat Identification and Analysis of Physical Processes

Location and Description of Study Area

Landscape Level

The study area is located along the right bank of the Sacramento River at approximately River Mile 194, approximately 4.5 miles west-southwest of the City of Chico in an unincorporated part of Butte County (see Figure 2). The study area includes the confluence of Big Chico and Mud Creeks with the Sacramento River and runs upstream on both creeks to the Sacramento River Conservation Area boundary (see Figure 3). The study area lies within the Sacramento River Conservation Area (SRCA) "Red Bluff-Chico Landing Reach," which is designated by the SRCA as Reach 2, and within The Nature Conservancy's "Chico Landing" sub-reach planning and management program (River Mile 184-206). Several landowners in the area are considering participating in conservation programs (see Figure 3). Detailed information on these parcels is contained within Appendix B.

While one specific project objective was to evaluate current conditions and identify critical habitat on the Singh parcel, the scope extends beyond this to the aforementioned confluence area surrounding the parcel due to the importance of looking at habitat, land use, and potential restoration at a landscape level, and because of the potential for additional neighboring landowner participation in conservation programs. As mentioned earlier, the importance of this confluence area from a physical and ecological process perspective is spatially much broader than just the Singh parcel. Activities on that particular parcel should not occur in a vacuum. Agricultural operations, restoration activities, infrastructure, river and creek migration, flooding patterns, and other issues elsewhere in the study area drive the selection of priorities and course of actions at any one location. Ultimately, through stakeholder processes, cooperative actions, and landscape level evaluations such as this, conceptual designs for areas along the river begin to emerge as a sort of "common blueprint"—a vision for a section of land that all can agree to and support. It was for these reasons that a spatially larger scope was chosen.

Historic Conditions of Study Area and Changes Through Time

Prior to Euro-American settlement, the study area was, in many ways, vastly different than it is today. Located in a unique position along the river where an alluvial fan, two flood basins, grass savanna, and several streams join, the study area was likely home to some of the highest biodiversity in the valley. Historically, during times of flood, the river spilled into the Butte Basin, which begins just south of Big Chico Creek, in the process nourishing extensive wetlands in this natural flood basin. The channels of Mud and Big Chico Creeks were more sinuous, had a less homogenous channel form, and in the case of Mud Creek, joined the Sacramento River though a much different route than it does today. The diverse habitat in the area included extensive grass savanna and oak woodlands bordering thick riparian areas along the streams themselves, creating unique ecotones.

Historically, there were over 500,000 acres of riparian forests along the Sacramento River (Katibah, 1984). Many bird and animal species that are now extirpated from the river corridor utilized this area for all or portions of their life histories. Written descriptions by John Bidwell, one of the earliest Euro-American settlers in the area, describe the study area and the areas surrounding it as being inhabited by grizzly bears (William Travers, *personal communication*, 2001). This should not come as a surprise as the grizzly generally exploited these areas, which were rich in fish and berries and other food sources (Dasmann, 1988).

In 1886, when the first surveys of the area to include topography and hydrology were conducted, the stream systems in the study area were vastly different than they are today (Figure 4). Mud Creek, in today's form, did not exist. Instead, it was joined by a branch of Sandy Gulch (now known as Lindo Channel) and flowed to the north to join Pine Creek in the marshy, low area of the Bosquejo Basin west of the town of Nord. Also important to note is that there appear to be no levees on any of the creeks in the study area, and Big Chico Creek has a distributary channel leading to the south from its left bank. By the time the survey for the map was conducted, a bridge (the Saint John Bridge, named for the small hamlet of Saint John located on the route to Hamilton City) had been constructed. For a short duration after it burned in 1903 a ferry was used at the site (Travers, 1997).

By 1904, when the next edition of the USGS map was prepared (see Figure 5), the landscape had already changed markedly. The most striking change is that Mud Creek now enters Big Chico Creek just above its confluence with the Sacramento River. Mud Creek no longer joins Pine Creek, and in fact, Kusal Slough, a distributary of Pine Creek that leaves that stream in the swampy area west of Nord, now comes south and joins Mud Creek just below today's Sacramento Avenue, a location it maintains to this day. The northern branch of Sandy Gulch that formerly split several times and rejoined to enter Mud Creek, is now straightened, channelized into one channel that meets Mud Creek, and is labeled "Channel Slough." The other branch of Sandy Gulch still flows to Big Chico Creek. However, Big Chico is now leveed on its left bank to below its confluence, where that levee then runs along the right bank of the Sacramento River.

The 1904 USGS map contains the first recorded survey of topography of the study area, and provides insight into the hydro-geomorphic processes sculpting the historic landscape. Recorded in the contour lines of this map is a representation of the topography created by various fluvial processes operating at several spatial and temporal scales. The study area appears quite complex—the junction of three rather distinct landforms: the distal end of the Big Chico Creek alluvial fan, the Sacramento River floodplain, and the downstream end of the Bosquejo Basin and the upstream end of the Butte Basin.

The rather symmetric contour intervals of the fan are visible in the right side of Figure 5, showing the conical shape of the lower end of the Big Chico Creek alluvial fan. Formed during the Pleistocene, (see Figure 6a), this gradually sloping feature acts as a geologic control (see Figure 6b) along the river, creating a significant topographic barrier to migration.

The Bosquejo flood basin, perhaps the least acknowledged of the flood basins along the Sacramento River, extends from the north into the study area (see Figure 6b). It receives flow from Singer, Pine, and Mud Creeks, other smaller streams, and overflow from the Sacramento River during times of high flow. Through time, floodwaters have carried fine sediment into the area creating fine textured soils that likely supported an extensive wetland/tule marsh, similar to the Butte Basin to the south. Floodwaters exit the area by flowing down through the study area and rejoin the river in the general area of the mouth of Big Chico Creek (see Figure 7).

The Sacramento River itself has obviously contributed to the landscape in the study area, not only from flood flows passing through the Bosquejo Basin, but also from lateral migration and avulsion. These processes have created the lands labeled as "100-Year Meanderbelt" in Figure 6b. However, they amount to a rather narrow band relative to other locations along the river up and downstream, owing to the strong influences of the Bosquejo Basin and Big Chico Creek alluvial fan as flood flows converge and "pinch" around the fan.

The Butte Basin lies just to the south of the study area, further increasing the complexity and hence ecologic importance of this part of the river corridor. The upper part of the basin begins as floodwaters from the river and Big Chico Creek start to overflow their left banks and begin to flow south and southeast, topographically "around" the distal end of the Big Chico Creek fan. As the river begins to spread into the Butte Basin after being constricted by the alluvial fan, it is joined by flows from Little Chico Creek and distributary channels from Butte Creek, all meeting on their way through the Butte Basin. By 1904 however, the USGS map (see Figure 5) shows that flows into the Butte Basin in this area were likely eliminated by levees along the left banks of Big Chico Creek and the river.

Moving ahead in the history of the site, data gleaned from a September 12, 1937 aerial photograph (see Figure 8) is the earliest vintage aerial photograph uncovered by this study which lends itself to analysis of historic conditions in the study area. By the time the photograph was taken, the landscape was undoubtedly vastly altered by Euro-Americans. This image provides the best visual clues for insights into historic landscape conditions in the area.

Perhaps most striking in the 1937 photograph are the vast extents of Valley Oak savanna grassland on the opposite bank of the Sacramento River (right bank). The local extent of Valley Oak savanna grassland habitat shown in this photograph is very impressive compared to the amount existing today. Further, it provides a bit of evidence indicating how dynamic river processes can be on opposite sides of the river: the occurrence of oxbows on the west bank, indicating channel migration and avulsion, is quite interesting juxtaposed with the alluvial fan and flood basin across the river. Albeit already extensively altered in the 1937 photograph, the east (left) bank of the river, with its drastically different habitat type, begs speculation as to the importance of patch size relative to dispersal of species, use of diverse habitat and ecotones by those species, and other ecological roles. Such occurrences demand further investigation into the role of such contrasting habitat types in close proximity along the river, relative to their importance in landscape-level ecological processes.

From the perspective of dominant ecological processes at the Singh parcel itself, this photo validates what current soil and geomorphic data have indicated for this area: the land between Mud Creek and the river (including the Singh parcel) is composed of recent alluvial deposits that *may* have been deposited relatively recently, but undoubtedly have been re-worked within the last 65 years. In the fall of 1937, when the photograph was taken, significant scour of the Singh parcel is clearly visible (indicated in Figure 8). Flows on the day of the photograph averaged 2,940 cfs (USGS, 2001), and recent peak flows preceding the date of the photograph included a flow of 117,000 cfs April 8, 1935, a flow of 133,000 cfs on Feb. 22, 1936, and a flow of 82,000 cfs on March 13, 1937 (*ibid*)[1]. It seems clear that the source of this scour can be traced upstream to an overflow area along the left bank of the river.

At least one conspicuous pattern, identified and labeled in the photograph (see Figure 8) appears to possibly be an old channel meander or channel avulsion scar. Based on GIS analysis, no channels have been identified in this area since 1896. This old channel appears to follow a curve similar to the curve in the river near the point where the abandoned channel is closest to the current location of the river in the photograph. Though the pattern is in a tilled field (further obscuring the clarity of the feature) the symmetric and narrow nature gives the appearance that the river may have moved west via dramatic avulsion, with subsequent lateral migration to the east bringing it back to its current location in the photograph. Further, this flow pattern joins Mud Creek in such a way as to suggest that the river formerly occupied this area, with the confluence of Big Chico Creek occurring a considerable distance upstream on its channel length from its location today.

The ecological importance of the dynamic channel migration patterns displayed in the historic record is significance. It is likely that the confluence of these three channels, return flow from the Bosquejo Basin, and the distributary to the Butte Basin created a highly dynamic situation relative to channel migration. This is possibly due to the transitory nature of deposition and scour at the mouths of these streams and the varying roughness associated with different stages of vegetation succession, all superimposed on the spatial template of a meandering river. Through relatively frequent disturbance, such a situation would create backwaters, eddies, side channels, sloughs, and other transitory features, all of which are important for native aquatic species. It has been recognized that channel migration and other forms of disturbance create habitat as well as destroy it, and in the absence of disturbance habitats tend to degrade, so that disturbance is a necessary part of habitat maintenance (Reeves et al. 1995; Naiman et al. 1992; Power et al. 1995 & 1996).

With the construction of Shasta Dam, occurring from 1938 to 1945, and impoundment and flow regulation beginning in 1945, came the perceived opportunities for expanded agricultural operations along the river. The 1949 Ord Ferry USGS

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[1] Flow records used here are from USGS Gauge # 11377100 "Sacramento R Above Bend Bridge Near Red Bluff, CA." The flow record for this gauge is the longest available, dating from March 1879. Peak flows at the site in the photograph were undoubtedly higher than those due to inputs from tributaries downstream. For the sake of comparison, peak flows indicated at the gauge for recent memorable floods were 152,000 cfs for Mar. 1, 1983, 134,000 cfs for Feb. 17, 1986, 127,000 cfs for Mar. 15, 1995, and 121,000 cfs for Jan. 1, 1997.

quadrangle (see Figure 9; updated via photorevision in 1969) shows that orchards have replaced the open, scoured land at the Singh parcel that was presumably used for grazing in 1937. This map and others adjoining it indicate that many other locations along the river in the vicinity of the study area saw the planting of orchards in this time period.

By the early 1940s, there was a concerted effort at hand to control flooding in portions of the Sacramento Valley. With the signing of the Flood Control Act of 22 December 1944, Public Law 534, Seventy-eighth Congress, Second Session, Section 10—Sacramento-San Joaquin River Basin (ACOE, 1961), a sum of over $65 million was specified for the Sacramento River and its tributaries and initial design criteria were evidently indicated in the act (*ibid*). The "Chico and Mud Creeks and Sandy Gulch" work unit was included in these planning efforts. In 1957, the initial project design flow estimates were revised upward likely due to an increasing data set of yearly flow data upon which to base flood frequency calculations. This change necessitated an increase in the design size of the Sandy Gulch (Lindo Channel) portion of the plan (ACOE, 1957). However, by this time, substantial encroachment by urban development along the banks of Sandy Gulch made purchase of rights-of-way cost-prohibitive (ACOE, 1961). Further, local interests viewed the plan as undesirable in its current iteration, and it was decided that a diversion of Big Chico Creek to Mud Creek would be the best plan (*ibid*).

This inter-basin transfer of floodwater from Big Chico Creek to Mud Creek was attained by: 1) improvements to the Five-mile Dam flood control structure (see Figure 10) on Big Chico Creek; 2) the construction of a diversion channel from Sandy Gulch leading to Sycamore Creek (a tributary of Mud Creek); and 3) the construction of a flood control structure limiting the amount of water leading into Sandy Gulch—effectively shunting the rest of flood flows to the Sycamore Diversion Channel. The functional outcome of this was that Mud Creek became a distributary of Big Chico Creek, albeit a controlled one. To control the significant increase in discharge, existing local flood control structures along the streams in the project were either enlarged in-place or set back and enlarged (ACOE, 1961).

While a detailed overview of channel capacities, operation and maintenance procedures, and issues related to them are beyond the scope of this document, the Big Chico Creek Existing Conditions Report (BCCWA, 2001) provides an excellent synopsis of this information and readers interested in such information are encouraged to consult that document. Despite the complexity in describing this system, several details and assumptions of the hydraulic design are important enough to this study that they are discussed here.

Hydraulic design of the lower portion of the Big Chico and Mud Creek project was based on two sets of flow conditions: Condition "A" was a flow of 12,000 cfs in Big Chico Creek at its confluence with the Sacramento River, and a flow of 210,000 cfs in the Sacramento River at the latitude of Ord Ferry. This corresponded to river stage of elevation 137.0 feet at the Big Chico/Sacramento River confluence and a flow recurrence of 50 years. This condition also assumed constrictions on the river by the then-authorized Butte Basin Plan and the now constructed Black Butte Project. Condition "B" was based on analysis of large floods on record to date and assumed that peak discharge at the mouth of Big Chico Creek preceded peak river discharge at that point by 8 to 20 hours. The project design outflow of 15,000 cfs for Big Chico Creek at its confluence with the river was used, and the stage of the river was set at elevation 134.0 feet. These two conditions and the assumptions contained within them are important when considering the current effectiveness of the flood control project along the lower reaches of the creeks, particularly in light of hydraulic changes (i.e. stage) in the river from channel migration, alterations in cross sectional area (natural and from riprap and levees), and subsequent changes in slope. Further, urbanization has likely altered changes in the flood hydrographs of Mud and Big Chico Creeks, namely increases in peak flow and in the timing and duration of the flood hydrograph, since the initial calculations for this project were completed.

In assessing the need for levees in certain areas of the lower creek (from Sacramento Avenue, downstream), The Army Corps of Engineers noted there was no need for a right-bank levee along Mud Creek since Kusal Slough joins it just downstream of this point. The ACOE considered this area to be Sacramento River floodplain (ACOE, 1961). Upstream, project design flows for the leveed section of Mud Creek below Highway 32 was limited to a flood frequency of only 50 years. This should perhaps be the starting point for any discussion considering the effectiveness of the flood protection being afforded neighboring landowners along the lower reaches of Mud Creek since upstream of Highway 32, that same channel was designed to handle flows with a frequency of once in 100 years.

In accordance with the required increase in channel cross section to accommodate floodwaters from Big Chico Creek, considerable portions of Mud Creek and Sandy Gulch, known as Lindo Channel after Army Corps of Engineers modification, were significantly altered. The scope of these modifications extends far upstream of the study area, and only those in the immediate study area are considered here. Design Memorandum No. 10 (ACOE, 1961) notes that reaches of Mud Creek contained existing local levees. To increase channel capacity, these existing levees would need to either be set back, expanded through channel excavation, and/or have vegetation removed. All floodways were to be constructed such that a minimum distance of 30-foot waterside berm between channel banks and the waterside toe of the levee existed (ACOE, 1961). The channel of Mud Creek, from its confluence with Big Chico Creek upstream to Kusal Slough, was enlarged and straightened with a minimum bottom width of channel of 80 feet (*ibid*). The channel was to have a waterway area to top of bank/levee three times that of the existing channel. The lower 1,500 feet of Kusal Slough to its confluence with Mud Creek was cleared of vegetation to a width of 100 feet on either side of the channel. The Big Chico Creek channel was cleared on either side for 50 feet, beginning at the River Road (then Sutter Avenue) bridge, upstream to its confluence with Mud Creek (*ibid*). The final outcome of these modifications is visible in Figure 9 by viewing the purple colored channel (photorevisions are done in this color). Levees on the left bank of Mud Creek extend from well above Highway 99 to nearly the mouth of Sycamore Creek. Noteworthy is the fact that this left bank levee ends approximately 900 feet before it meets Big Chico Creek. This was done to facilitate drainage of natural runoff, floodwaters from Big Chico Creek, and any water backing into the area from the river or creeks. Hence, this levee does little to eliminate flooding *per se*—rather, it seems its job was more to confine flood flows from Mud Creek to its channel, reduce the impact of flood velocities from river floods, and decrease debris inputs. The right bank levee along Mud Creek also begins far upstream, just downstream of Hicks Lane, however it ends just downstream of Sacramento Avenue before Kusal Slough enters on the right bank.

Current Conditions and Identification of Critical Habitat

Research and field reconnaissance for the assessment of current conditions was conducted during the months of June and July 2001. Additional information for analysis came via maps, a geographical information system (GIS), recent vertical and oblique aerial photographs, and site visitation with several local and regional experts in various disciplines. In an attempt to take an ecosystem processes perspective in describing conditions at the Singh parcel and study area, physical processes and alterations to them are described first, and the flora and fauna dependent upon those processes are discussed in turn.

Hydrologic Data

With over 100 years of hydrologic data collected for the Sacramento River, statistical flood recurrence can be calculated with much greater certainty than at the time of the projections made in the 1950s and 1960s. At that time, a much smaller data set (less years) was available. The California Department of Water Resources Northern District has since developed a layer of information in their GIS that lends a spatial sense to how often an *area* or zone along the river experiences flooding. The flood recurrence interval is the estimated probability of flooding of a given magnitude expressed in years. The extent of the 2.5-year recurrence interval flood for the reach of river between Keswick and Glenn was determined by digitizing 1:12,000 scale black and white aerial photos, taken in March of 1995, during a flood of a magnitude later estimated to be a 2.5 year flood event. DWR generated the other recurrence intervals using a computer modeling and a mathematical computation (DWR, 2001). A graphical output of this model is illustrated in Figure 11. The fact that the 2.5-year recurrence interval was digitized from photographs taken at the time of the "2.5-year flood, it ensures that areas in that zone and all others back toward the river are, on average, inundated once every 2.5 years (see zone labeled "2.5" in Figure 11). Since this recurrence interval data is based on actual flows, such data is generally quite reliable. In contrast, note how the zones further from the river are wildly angular, reflecting the uncertainty in the modeling efforts.

This flood recurrence data shows that on average once every five years some level of floodwater inundates much of the study area. One must consider that such a modeling effort may actually *underestimate* the frequency of flooding. This conclusion is due to the model's reliance on a single storm event, unique in its precipitation distribution. Since the model is based on main-stem river flows and not the tributaries, if this flow event was not representative of a tributary flood of 2.5 years, then the data may be misrepresentative in this area along the river. Indeed, during the stakeholder meeting for this study, neighboring landowners indicated that they felt the areas in the model shown as inundated every four years were actually wet more frequent than the stated interval. Nonetheless, the important implication for existing conditions analysis is that the study area is still, despite the protection afforded by Shasta Dam and local levees, subject to frequent flooding.

An integral part of any current conditions analysis should be an assessment of the available hydrologic data. However, data for Mud Creek is lacking. Table 2 exhibits USGS flow information data:

USGS Mud Creek Gauging Stations	Area in Mi^2	Period of Record
11384340 Mud Creek at Cohasset Road, near Chico	21.9	1968-69
11384350 Mud Creek near Chico	48.9	1966-74

Table 2: USGS flow information data (via USGS Website, 2001)

A search for data published by the California Department of Water Resources yielded no results. From the data above, it would be difficult to assess any trends in the hydrology of Mud Creek without more detailed study. Such work would likely be beneficial to understanding any impacts to the flood hydrograph by urbanization. Other data sources may be available from unpublished hydrologic and hydraulic studies undertaken as a part of either the Big Chico Creek Existing Conditions Report or through the ACOE or DWR related to channel maintenance.

Soils

Soil conditions in the study area are a major consideration for both the current agricultural operations in the study area and for any future restoration projects as well. As indicated earlier in this report, the Singh parcel itself is situated on soil of fairly good quality. The site is generally loamy: in the area of the Singh parcel, there is a strip of “higher velocity” fine sandy loam separating a band of silty loam from a separate strip of loam along the river (see Figure 12). Those soils are, running from the river to the west side of Mud Creek: Gianella Loam, Gianella fine-sandy loam, and Horst silty-loam. To the east of Mud Creek lies additional ground in Horst silt loam, but the lower portion of the flood basin begins to influence the soils here, expressed in the Kusal silty clay-loam soil. Along the channel of Big Chico Creek is a strip of Gianella fine-sandy loam, decreasing in width as it continues down the fan to the river. This soil also covers a patch of ground on the confluence peninsula between Big Chico and Mud Creeks.

Additional information on soil properties is contained in Appendix C. Based on past orchard production rates and soil productivity classification (Figure 13), the site appears to be of relatively good quality. Continued orchard operations and future riparian restoration activities would be well suited to this ground based solely on soil data. However, frequent flooding is a caveat to the aforementioned statement, and must be considered for both orchard operations and future restoration activities.

Hydro-geomorphic Processes

The concentration of the flow from numerous channels and distributaries into individual flood control channels that are relatively narrow and largely trapezoidal, is perhaps the most drastic alteration in physical processes in the study area. These straightened channels, coupled with the increased flow from Big Chico Creek, now funneled through Mud Creek, have caused a decrease in channel sinuosity, an increase in channel slope, and increased shear stress on the bed and banks. Any increase in urban runoff would exacerbate these changes. It is important to note that all storm water runoff for the City of Chico that does not go into Little Chico Creek or Comanche Creek, ends up at the confluence area through either Big Chico or Mud Creeks. And with the proposed Rock Creek/Kiefer Slough Flood Control Project, with one option being the transfer of floodwaters from those streams south to Mud Creek, a further increase in the discharge of Mud Creek would be created if such a project were constructed.

An interview with John Nock (*personal communication*, 2001) revealed that his land located at the confluence of Big Chico Creek and Mud Creeks was subject to flooding by Big Chico Creek far more frequently than by the Sacramento River. Further, according to his observations, during approximately the last decade, the creek has risen more quickly and peaked higher during storms—an event he attributes to increased urbanization in the upstream Chico urban area.

In recent years, significant erosion has occurred of the bed and banks on the lower reaches of Sycamore Creek, both directly at and just below its confluence with the Diversion Channel from Big Chico Creek, (Gibbs, *personal communication*, 2001). In this area, the channel, prior to the addition of floodwaters, was a relatively small stream with no significant scour holes or erosion into the underlying "fanglomerate" geologic structure. This lack of erosion is evidenced by comparing the drastic changes in channel conditions of Sycamore Creek upstream and downstream of the input of the diversion channel. Having received inputs from the Sycamore Diversion Channel, channel incision on Mud Creek is evident by the scouring of a City of Chico sewer line. This pipe, located upstream of Cohasset Road, was originally buried under the stream and is now fully exposed and undercut by the channel. During a site visit with Dr. Paul Maslin and Suzanne Gibbs (Big Chico Creek Watershed Alliance) in March 2001, additional scour was evident at several bridges downstream of Cohasset Road. All such erosion is taking place in the areas of Mud Creek and its tributary Sycamore Creek that are far upstream from the areas of these creeks affected by the backwater of the Sacramento River. As stage on the river rises, flows in the low gradient downstream reaches of Mud and Big Chico Creeks begin to slow as they meet what is now functionally a "backwater" of the Sacramento River. With the relatively narrow levees along Mud Creek, sediment carried by the stream has no place to go besides settle in the bottom of the flood control channel. Due to levees on both sides of the channel, and added sediment from channel erosion upstream, this is perhaps most dramatic on Mud Creek, beginning from the reach between Meridian Road and Sacramento Avenue, and continuing to Big Chico Creek. Depending on the storm, sediment may either be deposited in the channel, if the river is at high stage and the creek(s) have the discharge necessary to transport sediment. Another possibility is if the river is at a lower stage, the creeks may sluice this sediment down to where it meets the river backwater.

Site Level Description: Singh Orchard Parcel

Jaswinder Singh, Baldish Kauer Singh, and Sukhbir Singh currently own the 40 gross acre Singh walnut orchard parcel, based on the assessor's parcel map. The land is gently undulating yet conducive to the current farming techniques employed. According to a recent appraisal for the USFWS (Oakham, 2000), the land is planted in English walnuts of the Chandler variety, with Paradox rootstock. There are no structures on the property. The appraisal indicates that 39 of the 40-plus acres are in orchard, and that four acres of the parcel are not currently producing due to young age (~300 new trees were planted in 2000). A GPS survey conducted indicates that only 34 acres are planted in walnuts (Morris, *personal communication*, 2001). Older trees are planted on a 30-foot spacing, but younger trees are interplanted, one tree every fifteen feet, with the rows thirty feet apart, yielding an average 96 trees per acre. Field investigation for this study indicates that most of the ground in the orchard is covered in Bermuda grass. The appraisal states that an irrigation system consisting of a newly rebuilt 30-horsepower pump of low lift (~30 feet depth) and hand-moveable aluminum irrigation pipe is well paired to the topography of the site. The appraiser felt the orchard is in good condition with little or no disease present. However the report does indicate that the parcel lies completely within the FEMA designated Zone-A floodplain. It also indicates that the previous owner experienced orchard flooding twice during 18 years of ownership, and that in recent years (an undefined time period) the orchard has flooded another two times.

Adjacent to the Singh walnut orchard is a parcel of land in conservation ownership. The “Peterson Addition” as it has been termed, comprises over 80 acres and became part of Bidwell-Sacramento River State Park in Fiscal Year 1998. The USFWS-AFRP funded the purchase by the Sacramento River Preservation Trust and the land was then gifted to the State Department of Parks and Recreation. This acquisition protects native riparian habitat along its boundaries on Big Chico and Mud creeks, and preserves important natal and non-natal rearing habitat for juvenile spring-, fall- and winter-run Chinook salmon and steelhead. As mentioned above, this parcel adjoins a portion of the Bidwell-Sacramento River State Park, known locally as “The Washout.” With the Peterson Addition, conservation ownership by State Parks continues from the Singh Parcel down the right bank of Mud Creek and Big Chico Creek all the way to the confluence with the Sacramento River. This has preserved a sizeable amount of remnant riparian (~56 acres) as well as initiated restoration of the riparian forest on the Peterson Addition, ultimately creating a contiguous band of riparian habitat between the river and the creeks.

On-The-Ground-Observations: Singh Parcel

Observations made during a visit to the site on May 31, 2001 with Dr. Paul Maslin were recorded with a digital camera and in a field book. We utilized a canoe for a significant portion of the site visit thus allowing us to explore the entire confluence area to the mouth of Big Chico Creek at the Sacramento River. During the reconnaissance we explored the riparian habitat that recruited in sediment deposited along the expanding reach of Big Chico Creek (see Figure 1a and 1b) during the last 60-80 years. This area is now a mature riparian forest, thick with wild grape and home to roosting ospreys, egrets, and great blue herons (Figure 14 and Figure 15). At the time of field visit, we found that the Sacramento River backed up Big Chico Creek approximately 500 feet upstream from the Big Chico Creek/Mud Creek confluence. The backwater into Mud Creek went about 400 feet upstream of this point. Upstream of these points, flow in Mud Creek was much less than 1 cfs, and in Big Chico Creek was perhaps 2 cfs. According to Dr. Maslin, who had fished this same location for bass the previous summer, the area seemed to be much shallower this year (depth in these streams, gauged with a canoe paddle, ranged from less than a foot to over four feet). This observed temporal variation in depth from year to year is further evidence of the transitory nature of the sediment in this area—alternating from deposition in the channel to scour, based on the hydrology of the water year. Impacts to the ecosystem by this alternating pattern of deposition and scour in the incised channels of these two creeks was unknown, but Dr. Maslin speculated it was deleterious, and frequently re-set natural vegetation succession within the channel. During the time we surveyed the area, largemouth bass were visible in the deep pools of the creeks, thick algae was present, as was water primrose (*Ludwigia peploides* ssp. *Montevidensis)*, to the extent of making canoeing difficult.

Hiking upstream further on these streams gave the indication that the small flow of water remaining in the streams was sub-surface flow reemerging as it approached the saturated zone near the river's backwater. During a reconnaissance tour up the nearly-dry channel of Mud Creek (see Figure 16) to the latitude of the north boundary of the Singh parcel, a deer was encountered, as was a red shouldered hawk, non-native bullfrogs, and a non-native peahen and chicks. In this reach are numerous native vegetation species, but exotic vegetation does appear to be an issue for future examination. Himalayan blackberry (*Rubrus discolor*), Giant Reed (*Arundo donax*), pokeweed (*Phytolacca americana*), and yellow star thistle (*Centurea solstitialis*) were all identified along the banks of Mud Creek during this field tour. A noteworthy patch of native California wild rose (*Rosa californica*) exists on the left bank of Mud Creek near the end of the ACOE levee. Traveling along the left bank levee from Sacramento Avenue to the confluence of Big Chico and Mud Creeks shows that the vegetation removed in the 1960s has largely re-colonized, despite the clearing of this channel until some time in the 1970s (Nock, *personal communication,* 2001).

Not indicated on maps or initially clearly visible on vertical aerial photographs is a private berm on the right bank of Mud Creek (see Figure 17). As the ACOE decided that the area between the river and Mud Creek was river "floodplain" and no levee was built, it seems that thru time private interests along the right bank of Mud Creek began to construct a flow barrier of sorts to eliminate overflows and debris from the stream. This may also have been a convenient multi-purpose solution for the sediment and debris that gets deposited in the orchards during floods. It seems the ACOE considered the left bank levee along the creek important in terms of controlling the forceful flows from the river, but perhaps thought less of the right bank overflow of Mud Creek across lands going toward the river. Certainly, the creek in its post-ACOE project format was carrying considerably more water than it had ever before. It is not surprising then that even when the river is not flooding across the Singh, Peterson, and other parcels to the north, Mud Creek has the potential to flood across these lands and deposit sediment and large woody debris.

The topography of the Singh parcel is fairly well preserved (see Figure 18); the site has not been totally leveled (just smoothed), and in fact contains the remnants of the scour/swale features that are visible in Figure 8. This swale is topographically connected to the river on the upstream end, and still maintains natural connectivity to Big Chico Creek and the river as it flows through the Peterson Addition and to the south (see Figure 19a and 19b). Remnant natural topography on agricultural land is unique along the river, and gives this parcel, and those adjoining it, priority over others that have been extensively leveled.

Critical Habitat for Species of Concern

Salmonids

Juvenile Chinook salmon of all races (spring, fall, late fall and winter run) and steelhead trout, as well as non-game fish species including Sacramento sucker, Sacramento pike-minnow, hardhead, hitch, tule perch and Sacramento splittail have been documented rearing in the tributaries flowing through or near the study area (see Figure 20) (Paul Maslin, *personal communication*, 2001). Through the project area, Mud Creek, despite its current configuration as a flood control channel, is perhaps the most important non-natal rearing habitat for juvenile salmonids—particularly for winter-run Chinook, along the Sacramento River (Maslin *et al*., 1999). During sampling from 1993 through 1998, Maslin *et al.* consistently observed more juvenile Chinook salmon using Mud Creek for rearing than any of eighteen other tributaries sampled. The exception was in 1996/97, when the Pine Creek /Rock Creek/ Kusal Slough complex, just to the north of Mud Creek, harbored more juvenile fish. During times of flood, this area can become connected to Mud Creek. The tributary fish sampled were found to be in excellent condition and to smolt and emigrate earlier than fish in the river. It has been estimated that between 100,000 and 1,000,000 juvenile salmonids rear in the lower portions of the Sacramento River's intermittent tributaries (Maslin, *et al*., 1999). During field investigations with Dr. Maslin for this study, he conveyed his opinion that the entire confluence area was extremely important as rearing habitat for juvenile salmonids and felt that restoration at the site would be highly beneficial and cost-effective (Paul Maslin, *personal communication*, 2001).

Other research (Sommer, *et al.*, 2001; Sommer, *et al.*, 2000) indicates that fish rearing on inundated floodplains (in the cases cited, the Yolo Bypass, the primary floodplain of the lower Sacramento River) show increased growth rates, larger size at recapture, and perhaps greater survival compared to a similar group of fish in the main stem of the river. These researchers found greater availability of drifting invertebrates in the river floodplain habitat and suggest that the higher prey consumption of the fish accounts for the higher growth rates.

Junk *et al.* (1989) proposed the "flood-pulse concept" as evidenced by showing increases in drift invertebrates on river floodplains over that of the main stem river channel. This concept states that the primary force that determines biotic interactions and productivity in a river system is annual inundation of the floodplain (Junk *et al.*, 1989; Bayley, 1991; Sommer *et al.*, 2000). This typically annual flood-pulse process is speculated to enhance productivity and maintain diversity through agents such as sediment, nutrients, vegetation, and detritus via the predictable advance and retraction of water on the floodplain (Bayley, 1995). The land in the study area still maintains some semblance of floodplain connectivity, and if enhanced would enable benefits of the flood-pulse process for the Sacramento River aquatic ecosystem.

Past research conducted on restoration efforts, particularly those for juvenile Chinook salmon, indicate that construction or rehabilitation of off-channel habitat may prove beneficial for juvenile salmonid rearing (Richards, *et al.*, 1992). "…(T)here is emerging recognition of the role of natural geomorphic processes of floodplains in supporting a variety of sensitive fish species and supporting food webs" (CalFed ERP Draft Stage 1 Implementation Plan, 2001, p. 29) though there remain numerous questions related to required system inputs, magnitudes, and feedbacks to other systems when conducting rehabilitation activities (CalFed ERP Draft Stage 1 Implementation Plan, 2001). Maslin *et al.* (1999) note that while due to limits in data collection the importance of intermittent tributary habitat cannot be ranked relative to other habitat types, especially considering the amount of such habitat already lost in the Sacramento Valley. The observed benefits to juvenile fish in these areas, the preservation, and restoration of intermittent stream habitat should be a priority. Restoration based on strategies that acknowledge the benefits of the flood-pulse will enable system functions that provide higher productivity and offer system resilience (Bayley, 1991). Opportunities to restore intermittent tributary habitat, while simultaneously reconnecting such a stream with its floodplain, would presumably be highly beneficial for juvenile salmonids and other aquatic species. The swale and natural topography preserved on the Singh parcel is a fortunate occurrence and is very important when considering future conservation management of the area, particularly if an emphasis is placed on juvenile salmonids and other fish species utilizing this area for habitat.

Avian Species

Though no more important than aquatic species in the river environment, a dramatic decline in certain avian species and their habitats drove much of the early conservation literature and planning efforts on the Sacramento River. Restoration of the river's fishery has received considerable attention, particularly of late. Preliminary restoration has largely come in the form of structural modifications and additions to fish screens, diversion dams, and fish ladders. Additionally, these actions have largely been focused on the tributaries to the river, and only now is a more holistic focus being taken on the mainstem in terms of in-stream and floodplain habitat. In accordance with this history, there is a greater amount of literature and focused action related to the restoration of riparian habitat and avian species, most notably the Riparian Habitat Joint Venture (2000).

Riparian areas are the most critical habitat type for conservation of Neo-tropical migrant and resident birds in California (Manley and Davidson, 1993) and throughout the west (Rich, 1998). During an avian survey of the Singh parcel (0800, July 16, 2001) undertaken for this report, Stacy Small of the Point Reyes Bird Observatory, who was assisted by the author, documented 24 bird species including the non-native Brown-headed Cowbird in the riparian and non-agricultural field areas bordering the walnut orchard which dominates the land use on the parcel. Only eight avian species were documented in the walnut orchard itself. Full lists of avian species observed are given in Appendix D. As a consequence of the importance of such habitat, the loss of riparian areas may be the most important cause of population decline among land-bird species in western North America (DeSante and George, 1994). Riparian areas provide very productive breeding grounds, but also offer crucial over-wintering and migration stopover areas (Ralph, 1998). Riparian areas also create the corridors for dispersal that are used by avian species to establish new territory (Riparian Habitat Joint Venture [RHJV], 2000).

Habitat loss and degradation are probably the most important factors related to the decline of riparian birds (RHJV, 2000). The following disruptions to the riparian system have contributed to the degradation of habitat: Emplacement of dams and levees has altered natural hydrological conditions, as well as decreased channel dynamics. Additionally, land clearing associated with farming and development, over-grazing and the invasion by exotic species have all contributed to the destruction of riparian zones (RHJV, 2000 Given all factors, the associated nest predation and parasitism by the Brown-headed Cowbird also reduces the reproductive success of many riparian birds in California (Gardali *et al*., 1998; USFWS, 1998).

Some scientists have suggested that the loss of wintering grounds in the Neotropics is an important factor limiting migratory bird populations (Rappole and McDonald 1994), however long-term studies of migrant land birds in California suggest that reproductive success on the breeding grounds is the primary factor limiting populations (Johnson and Geupel 1996, Chase et al. 1997, Gardali et al. 2000). Given these findings, the Point Reyes Bird Observatory has begun monitoring work along the Sacramento River and its tributaries aimed at measuring reproductive success of numerous riparian bird species (S. Small, Personnel Communication, July 16, 2001).

Alteration or elimination of riparian landscapes acts to narrow or destroy important population dispersal corridors; disturbed sites often have a higher density of non-native avian predators than would naturally occur (RHJV, 2000). At this time, western Yellow-billed Cuckoos are failing to disperse to new areas from healthy populations. This failure is speculated to perhaps be a function of the population distance from appropriate habitats (Laymon, 1998). The longer distances between appropriate habitat patches may not be difficult for long-distance migrants to cover between breeding seasons, but they may pose insurmountable problems in attracting mates during the breeding season (Laymon, 1998). Preservation and restoration of riparian vegetation at tributary confluences along the Sacramento River would function to greatly expand the potential for dispersal of sensitive avian species such as the Yellow-billed Cuckoo. While acting to link together other patches of riparian habitat along the river, it also enables the potential for dispersal of these species to the habitat found in the lower foothill portions of the Sacramento River tributaries (PRBO, 2001).

Habitat features around the nest and at a landscape scale affect levels of nest parasitism and predation (Larison et al. 1998). The expansion of agriculture and urban land conversion tends to enhance favorable conditions for native and non-native predators that decimate bird communities. As a result of the conversion of native habitats to farms and pastures, the Brown-headed Cowbird has undergone a population explosion and range expansion during this century (Lowther 1993). This increase is largely due to the expansion of agriculture and livestock grazing near riparian zones giving the Brown-headed Cowbirds ample foraging habitat close to songbird breeding grounds (Mathews and Goguen, 1997). The elimination of top predators, such as mountain lions and wolves, results in an increased population of mid-level predators. These animals, including raccoon, fox, skunk, domestic cat, and opossum are well-documented avian predators (Soulé et al. 1988). Land conversion also favors nest predators such as jays, crows and magpies.

As noted earlier, on July 16, 2001, the author accompanied Stacy Small of the Point Reyes Bird Observatory, Sacramento River Project to the project site to undertake reconnaissance for avian species of concern and to assess the value of existing and potential habitat. Far more birds were seen in the surrounding riparian areas and abandoned agricultural fields (on the Peterson Addition to the south) than in the orchard itself. The birds observed in the orchard were foraging adults and family groups that probably nested in nearby riparian habitat, not in the orchard (S. Small, Personnel Communication, July 16, 2001). Some older walnut orchards with decadent trees provide cavity nest sites, but the orchard on the Singh property does not support trees old enough for cavity nesting, and Ms. Small attributes the lack of breeding in the orchard to this fact. Further, she noted that the orchard also lacks understory structure. This deficiency accounts for the absence of nest sites for shrub and herb nesting species.

The study area is located directly across the river from the Kaiser Slough Unit of the USFWS Sacramento River National Wildlife Refuge (see Figure 21). PRBO annually observes the Kaiser site—a location that ranks as the second highest of 24 sites surveyed in terms of species richness during the year 2000 point sampling (31 species recorded, and an average of 44 individuals recorded per point). Point sampling is unique in that a trained biologist records all bird detections by sight, song, and call within a five-minute period, at each point on a survey route. Special note is also made of any breeding activity observed. The species richness observed at this site would be beneficial to any restoration efforts at the Sign property. Ms Small noted that, as related to Appendix D, all species identified during the July 16, 2001 survey in riparian areas could potentially colonize an adjacent restoration site. Some of these species, such as the Spotted Towhee, Lazuli Bunting, Black-headed Grosbeak, and Common Yellowthroat, have been known to breed on riparian restoration sites on the Sacramento River (such as TNC's Pine Creek and Flynn restoration sites) within 3 years of planting.

Stakeholder Input

Neighboring landowners and interested stakeholders were invited to a meeting where the information in this report was shared and stakeholders were encouraged to share their experiences of the study area and submit input on the idea of restoration in the study area. The following points were captured during that meeting and recommendations for future actions relative to conditions in the study area were examined:

Stakeholder Notes on Existing Conditions:

- Creeks flood more often than the Sacramento River. Water backs-up in big river events.
- The area floods more often than DWR flood estimates. The group assumed the DWR estimates do not include tributary input.
- Flood patterns are different depending on source (storm, snowmelt, location of storm, temperature, duration, etc.)

Stakeholder Recommendations:

- Protect existing levees and infrastructure for adjacent farming operations.
- Consider notching or removing the "berm" along Mud Creek on the Singh and Peterson parcels to reduce flood pressure on the Nock parcel.
- Consider across-stream effects on neighboring properties. Mud Creek channel was maintained clean until the mid 1970's(?), consider increasing channel size, or decreasing vegetation to improve capacity.

- Consider modeling channel capacity (historic, current, and potential restored) using HEC-RAS to determine effects of restoration actions and alternate scenarios for managing natural vegetation in the channel.

- Comprehensive solutions should be sought that address flood control and optimize habitat.

John Merz, of the Sacramento River Preservation Trust, was involved in the transfer of the Peterson Addition to State Parks. During an interview for this report (*personal communication*, 2001) he mentioned that during that real estate transaction, it was assumed that the "rumored" deeding of a strip of land along the north (right) bank of Big Chico Creek by Annie Bidwell to the County of Butte was still in existence. However, a search at the Butte County Assessors Office for this report returned no record of a parcel of land extending along the right bank (north side) of Big Chico Creek, nor any easements. Such an easement would allow increased flexibility in conservation management of the study area. The reason for the disappearance of that parcel is unknown to staff Assessors Office. Further examination of changes in title for surrounding parcels may provide an answer.

Section IV: Summary and Recommendations

Summary

Despite human alterations to the study area, its ecological significance is high. While landforms and key hydro-geomorphic processes are significantly altered from natural conditions, the hydrographs of these un-dammed tributaries are relatively natural and intact, providing a sound basis for restoration efforts in this area. The natural hydrographs of the tributaries provide the temporal and spatial temperature regime that native aquatic species have evolved with. There is significant existing use of the study area by anadromous fish rearing. During five years of sampling, Maslin *et al.* (1999) consistently observed more juvenile Chinook salmon using Mud Creek for rearing than any of eighteen other tributaries sampled. The tributary fish sampled were found to be in excellent condition and to smolt and emigrate earlier than fish in the river. Estimates indicate that between 100,000 and 1,000,000 juvenile salmonids rear in the lower portions of the Sacramento River's intermittent tributaries (Maslin, *et al*., 1999). Restoration of the study area is expected to bring significant benefit to rearing salmonids (Paul Maslin, *personal communication*, 2001).

Although the existing habitat for neotropical migrant birds in the study area is of moderate quality, the potential value would be high following restoration measures. Were the area restored, avian species from the neighboring Kaiser Slough Unit of the Sacramento River National Wildlife Refuge, located directly across the river from the Singh parcel, could easily colonize restored portions of the study area (Stacy Small, *personal communication*, 2001).

The site also has deep alluvial soils with natural drainage features, an important ecological characteristic not often found on agricultural lands, making it ideal for riparian forest restoration. Depending on future site-specific restoration planning efforts, a variety of native riparian vegetation communities may be restored based on the soil conditions and the needs of flood managers. A key feature on the site is the intact topography, most notably an overflow swale feature. This feature drains to Big Chico Creek, flowing through the downstream Peterson Addition (currently being restored) along the way. This natural drainage greatly diminishes the potential for stranding of juvenile salmonids on the site when floodwaters that have inundated the site recede.

The study area is at the downstream end of a regional flood overflow area (the Bosquejo Basin), as well as a federal flood control channel (Mud Creek). As such, the area plays a crucial role as both habitat and flood control. Local landowners have indicated they would support a more naturalized channel design if it ensured an increase in floodway capacity. An increase in flood-flows through the study area as a part of the proposed Rock Creek/Keefer Slough flood control system presents the possibility of higher average discharges through Mud Creek and the need for even greater floodway conveyance in the study area. As such, restoration efforts in the area would offer benefits for both the ecosystem and flood safety.

The Nature Conservancy Sacramento River Project, as a part of its Chico Landing sub-reach planning efforts, has created a 2-dimensional hydraulic model for use in assessing the hydraulic impacts of different restoration scenarios along the river in the area upstream of Chico Landing. This model allows for varying the land use and land cover of lands along the river to gain the hydraulic outcome (depth, velocity, flow direction) of potential restoration actions. This very important tool, already in place, can assist in examining possible restoration strategies for the study area.

The goal of the AFRP (as stated in Section 3406(b)(1) of the CVPIA) is to "develop within three years of enactment and implement a program which makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991." The opportunities for restoration in the study area present the possibility of reaching that goal through the attainment of several of the six general objectives stated by the AFRP as necessary to achieve the program goal. The AFRP objectives related to this area include:

- Improve habitat for all life stages of anadromous fish through provision of flows of suitable quality, quantity, and timing, and improved physical habitat
- Improve the opportunity for adult fish to reach their spawning habitats in a timely manner
- Collect fish population, health, and habitat data to facilitate evaluation of restoration actions
- Involve partners in the implementation and evaluation of restoration actions

This study has provided a look into the history and current condition of the Big Chico Creek/ Mud Creek confluence area to demonstrate it's ecological importance and evaluate the opportunities for habitat restoration. The Big Chico Creek/Mud Creek confluence area presents excellent opportunities for protecting and restoring habitat critical for anadromous fish, neotropical migrant bird populations, and riparian forest communities. This study represents the initiation of a concerted effort to begin gathering information and data useful in formulating and evaluating restoration actions in the area of the Mud Creek/Big Chico Creek/Sacramento River confluence area. It also presents a comprehensive strategy for restoration and specific recommendations to ensure "due diligence" for evaluation of proposed restoration actions.

Restoration Strategy and Recommendations

An important strategy in the protection and enhancement of rearing habitat for anadromous fish and riparian floodplain vegetation is the selective removal or realignment of levees, berms, revetment, and other flood control features at the confluence of Mud Creek and Big Chico Creek with the Sacramento River. Local landowners have indicated they would support a more naturalized channel design if it ensured an increase in floodway capacity. As such, restoration efforts in the area would offer benefits for both the ecosystem and flood safety. Based on the findings of this report and input from stakeholders, the following conservation actions are recommended:

1. Establish conservation programs with willing landowners adjacent to Mud Creek and Big Chico Creek within the Sacramento River Conservation Area. The Nock and Singh parcels are priority acquisitions for several reasons:
    - The current landowners are willing sellers
    - The parcels are adjacent to existing conservation ownership (Bidwell-Sacramento River State Park)
    - These are the obvious parcels needed to allow Mud and Chico Creeks to access their floodplains
    - Restoration of floodway capacity would improve flood safety for land upstream, yet have no undesirable downstream effects at these parcels;
    - Restoration of riparian vegetation would provide high quality habitat for neotropical birds.

2. Restore landforms to improve floodway capacity and channel-floodplain connectivity:
    - The berm on the Singh parcel could be removed to provide an immediate increase in floodway capacity, improve channel floodplain connectivity for anadromous fish use, and would not cause undesirable flooding on downstream parcels. Restoring channel capacity by removal of the berm instead of clearing the channel will save and restore aquatic and near shore habitat crucial for salmonids, and increase channel floodplain connectivity.
    - Provided conservation ownership is attained, the left bank levee along Mud Creek through the Nock parcel (across Mud Creek from Singh) could be removed. This would provide even more additional floodway capacity and would greatly improve the extent of accessible floodplain to anadromous fish at certain water levels.
    - The excavation of the ACOE flood control project created the incised creek channels found today which reduce the streams' ability to access the floodplain during more frequent flood events, and decrease the duration of that time out-of-bank. As increasing the elevation of the stream bed of these channels is impossible, any efforts to *decrease* the elevation of the overbank areas would provide a similar function. If the removal of berms and levees is undertaken, and through adaptive management and monitoring this course of action proves to be insufficient to reconnect the floodplain under typical winter flow conditions, this connectivity could be attained by excavating to a new floodplain elevation in a portion of the area currently occupied by the Nock orchard, and perhaps on the Peterson Addition and Singh parcel as well. This is a costly alternative, and the extent to which such an effort is prudent would need to be determined through additional modeling exercises and consultation with aquatic habitat specialists.

3. Restore native plant communities to improve floodplain habitat. Active planting (horticultural restoration) of native vegetation species appropriate to the soil and

hydrologic/hydraulic conditions of the site is recommended for acquired parcels. The existing orchards have an aggressive, well-established perennial weed understory that offers serious competition to native plantings. As such, an important step in out-competing these invasive species is the irrigation of native species and weed control. It is recommended that "Mixed Riparian Forest" be planted throughout much of the Singh and Nock parcels, with an attempt being made to naturally grade this vegetation type into a more xeric, and hence less dense, "Valley Oak Forest" and "Valley Oak Savanna" further upstream (on the Mendonca parcel and the upstream portion of the Nock parcel). The planting of the full extent of this gradation is dependent upon additional landowner participation. Enhancement of the swale/river distributary channel that flows through the Singh parcel could be accomplished by planting herbaceous species (i.e. *Carex sp.)*, though Willow Scrub (Arroyo willow, Black willow, Box elder), currently established in parts of the swale in the downstream Peterson Addition, could be another potential vegetation type to consider. Detailed soils analysis and additional hydraulic modeling is an essential part of developing plant designs and channel configurations.

4. Ensure long-term management and coordinated conservation ownership. Bidwell Sacramento River State Park is the best candidate for long-term ownership and management of acquired parcels because they are adjacent landowners, have on-site staff, and they have expressed an interest in owning the parcels following restoration activities.

Benefits of Floodway Restoration

The anticipated long-term ecological benefit of a coordinated process-based and active restoration program for the Big Chico Creek/Mud Creek confluence area floodplain is the permanent protection of this unique river floodplain/confluence area and the sustaining processes derived from an intact system. Important physical processes (and hence ecological processes) that create and maintain natural channel and bank conditions would be restored including sediment transport, channel erosion and deposition, and increased temporal and spatial connection of the creek with the floodplain during times of high flow. Such processes would enable increased use of floodplains by juvenile fish for rearing. Ecologically, these confluence areas would help to achieve increases in inundated areas with all the associated benefits of the river pulse concept (Junk et al., 1989). The restoration of this area would also restore riparian forest and streamside vegetation and enable ecological succession. Consistent with SB1086 objectives, this would contribute to the long-term goal of restoring an extensive and continuous riparian forest corridor that would help reduce flood damage, create aquatic habitat structure, and benefit the aquatic environment by contributing shade, overhead canopy, in-stream cover and juvenile rearing habitat, and runoff filtering capacity.

In 1961, the only concern for fish and wildlife related to the ACOE Big Chico Creek flood control project was related to the stranding of up-migrating adult salmonids and some concern for decreases in riparian vegetation in Bidwell Park (ACOE, 1961). Today, the importance of the entire life cycle of anadromous salmonids, particularly juvenile out-migrants, has been shown to be critical, along with the interconnectivity of the entire ecosystem. Efforts to restore the lands in the study area represent a holistic restoration strategy and appear as a unique opportunity to restore and preserve a crucial link in the riverine-tributary continuum.

Additional Recommendations

This report was a reconnaissance level effort to determine restoration opportunities and strategies for the Big Chico Creek / Mud Creek Confluence area. Additional research and modeling needs arose through this planning process and from comments received at the stakeholder meeting. The following detailed investigations would help inform community-planning efforts and assist in developing specific management objectives for the study area:

- Develop a regional drainage network hydraulic model to examine alternate scenarios of future upstream development (such as Rock Creek/Keefer Slough, Chico urban expansion, etc). The outputs from this model would optimize the effectiveness of several of the following recommendations.

- Acquire and utilize updated site-specific stage-discharge data for the Sacramento River at Big Chico Creek (completed by the ACOE) to provide downstream water surface elevations for 2-D hydraulic modeling.

- Utilize existing 2-D hydraulic model to determine channel capacity of tributaries in conditions to include historic, current, and potential restored, to evaluate floodway restoration alternatives (such as levee removal or realignment, re-vegetation, etc.) and scenarios for managing natural vegetation in the channel.

- Undertake detailed investigation of channel hydraulics (shear stress, channel capacity, etc.) for Mud Creek, and include in this the Sycamore Creek erosion problem downstream of the inputs from the Diversion Channel. A portion of this investigation should consider the impacts to both the ecosystem and existing infrastructure and private property were the proposed Rock Creek/Keefer Slough diversion project constructed.

- Determine the stage and discharge when the Sacramento River backs up onto or flows across the Singh and Peterson parcels.

- Determine the stage and discharge when Big Chico Creek flows out of its right bank and heads north across the Nock parcel. This study needs to be modeled with the Sacramento River at various stages.

- Initiate a monitoring program to evaluate the effects of restoration actions and to determine to what degree upstream alterations in the watershed will impact restoration success.

- Examine effectiveness of ACOE levee system in the area based on the river stage of elevation 137 feet (“Conditions A”) used by the ACOE for design of the system.

- Continue detailed mapping of non-native vegetation in the study area already started on Peterson Addition.

- Conduct archeological survey prior to any changes in land management.

- Investigate title records for the “missing” County of Butte parcel/easement along the north bank of Big Chico Creek.

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United States Fish and Wildlife Service (USFWS). 2001. Final Restoration Plan For The Anadromous Fish Restoration Program: A Plan to increase Natural Production of Anadromous Fish in the Central Valley of California. Prepared for the Secretary of the Interior by the United States Fish and Wildlife Service with assistance from the Anadromous Fish Restoration Program Core Group under authority of the Central Valley Project Improvement Act. Released as a Revised Draft on May 30, 1997 and Adopted as Final on January 9, 2001.

U.S. Fish and Wildlife Service (USFWS). 1998. Draft recovery plan for the least Bell's Vireo. U.S. Fish and Wildlife Service, Portland, OR. 139 pp.

United States Geologic Survey (USGS). 2001. Web based retrieval of historic peak flows for Sacramento River gauge at Bend bridge near Red Bluff (USGS Gauge # 11377100). http://water.usgs.gov/ca/nwis/peak?site_no=11377100&agency_cd=USGS&format=html

Vannote, R.L., Minshall, G.W., Cummins, K.W., Sedell, J.R., and Cushing, C. E. 1980. The River Continuum Concept. *Canadian Journal of Fisheries and Aquatic Sciences,* Vol. 37, pp.130-137.

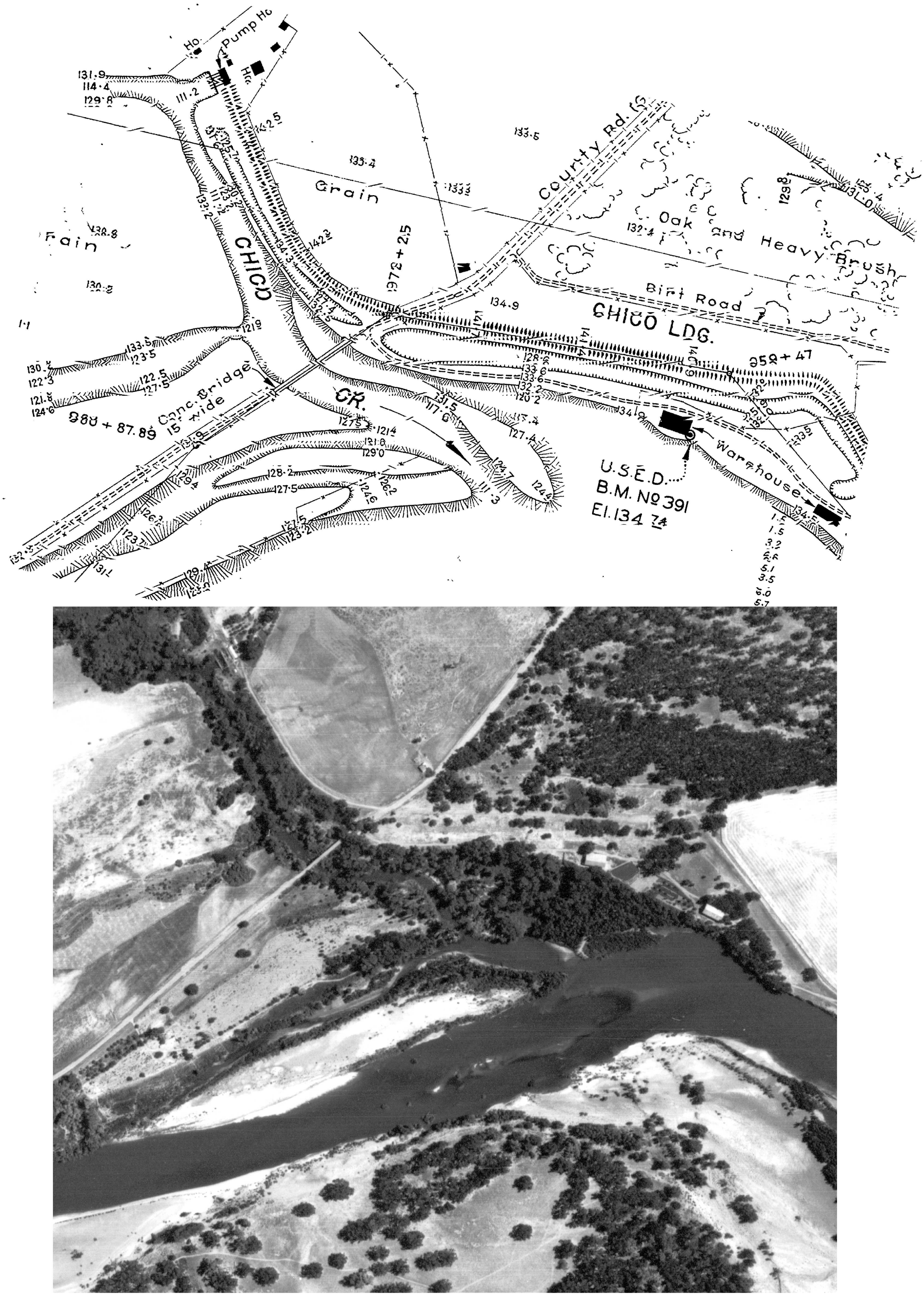
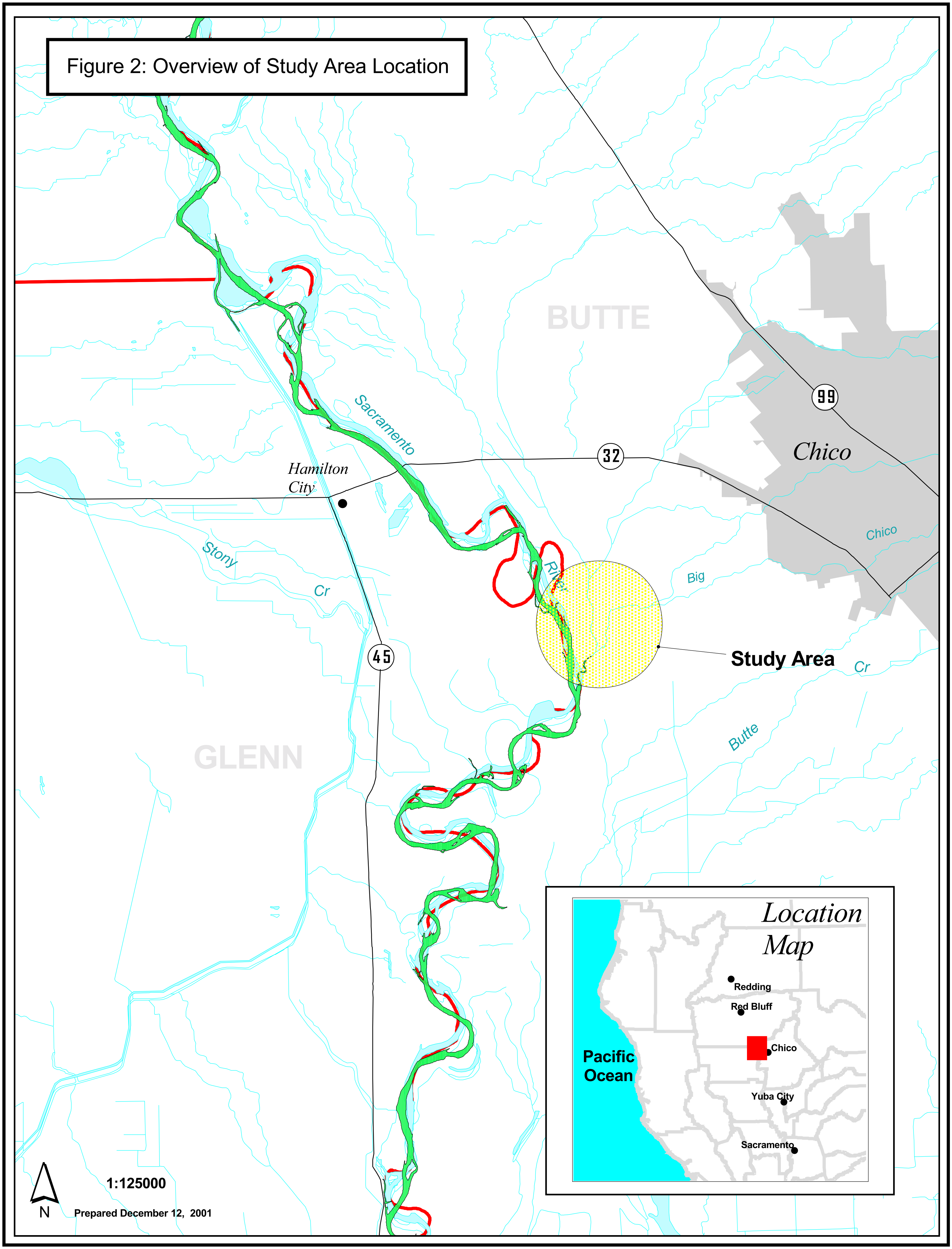


Figure 1a. Top: 1937 ACOE map of Chico Landing area; Bottom: 1937 photograph of same area. Note how vegetation between road and river has not yet recruited in these photographs, and side channel of river that feeds to mouth of creek has only emergent vegetation. Barn visible in lower photograph is identifiable in Figure 1b.

Figure 1b. Two views of the Chico Landing area taken in July, 2001. Discrete bands of cottonwoods (*Populus fremontii)* can be seen established along the former side channels of the river. As the river has migrated, and sediment has deposited, the length of the creek has grown and the extent of riparian habitat has increased. Bridge over Big Chico Creek is visible in both photographs.

Figure 2: Overview of Study Area Location



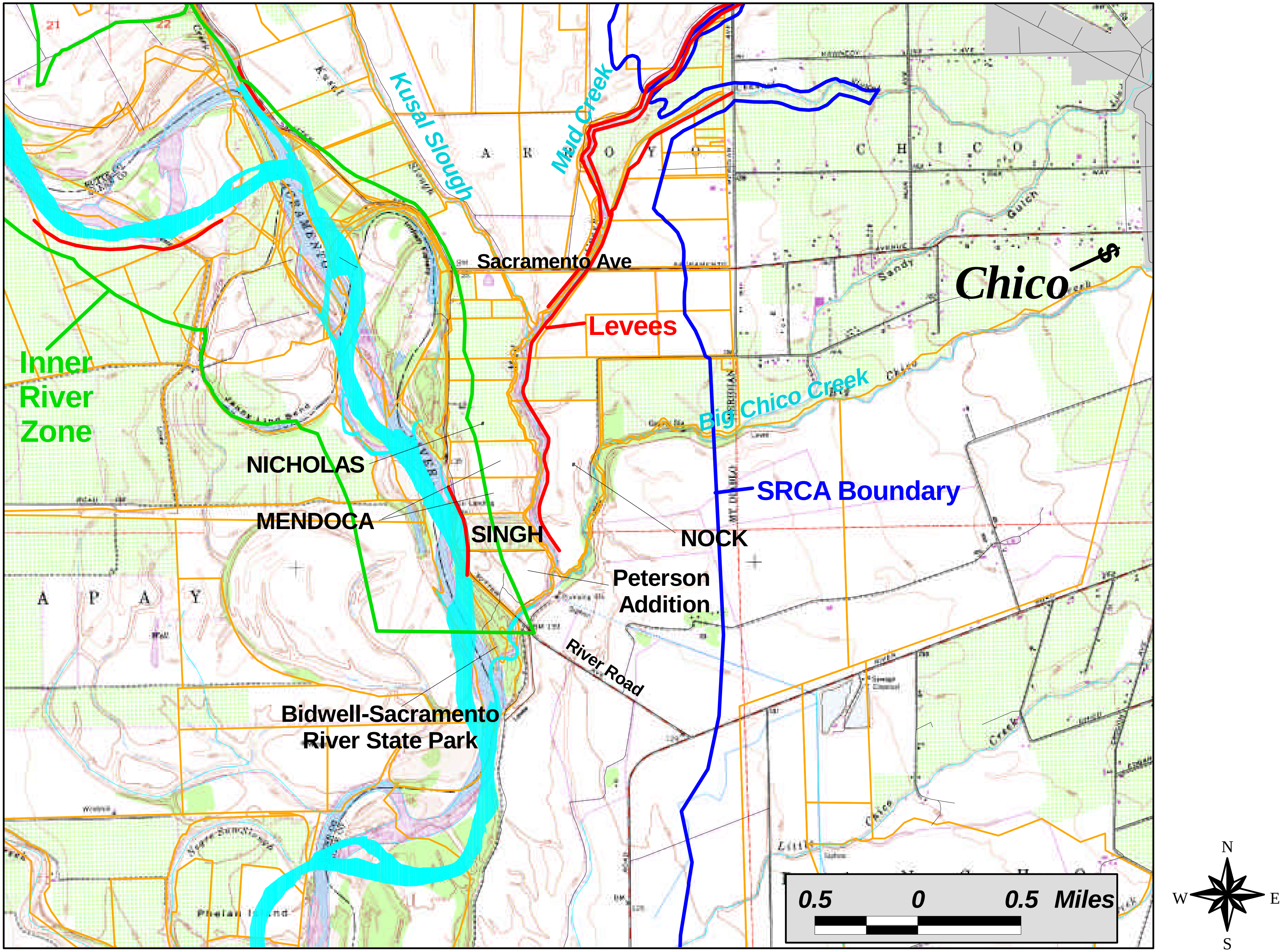


Figure 3: Overview of study area. Source: DWR, 2001; CSUC GIC, 2001.

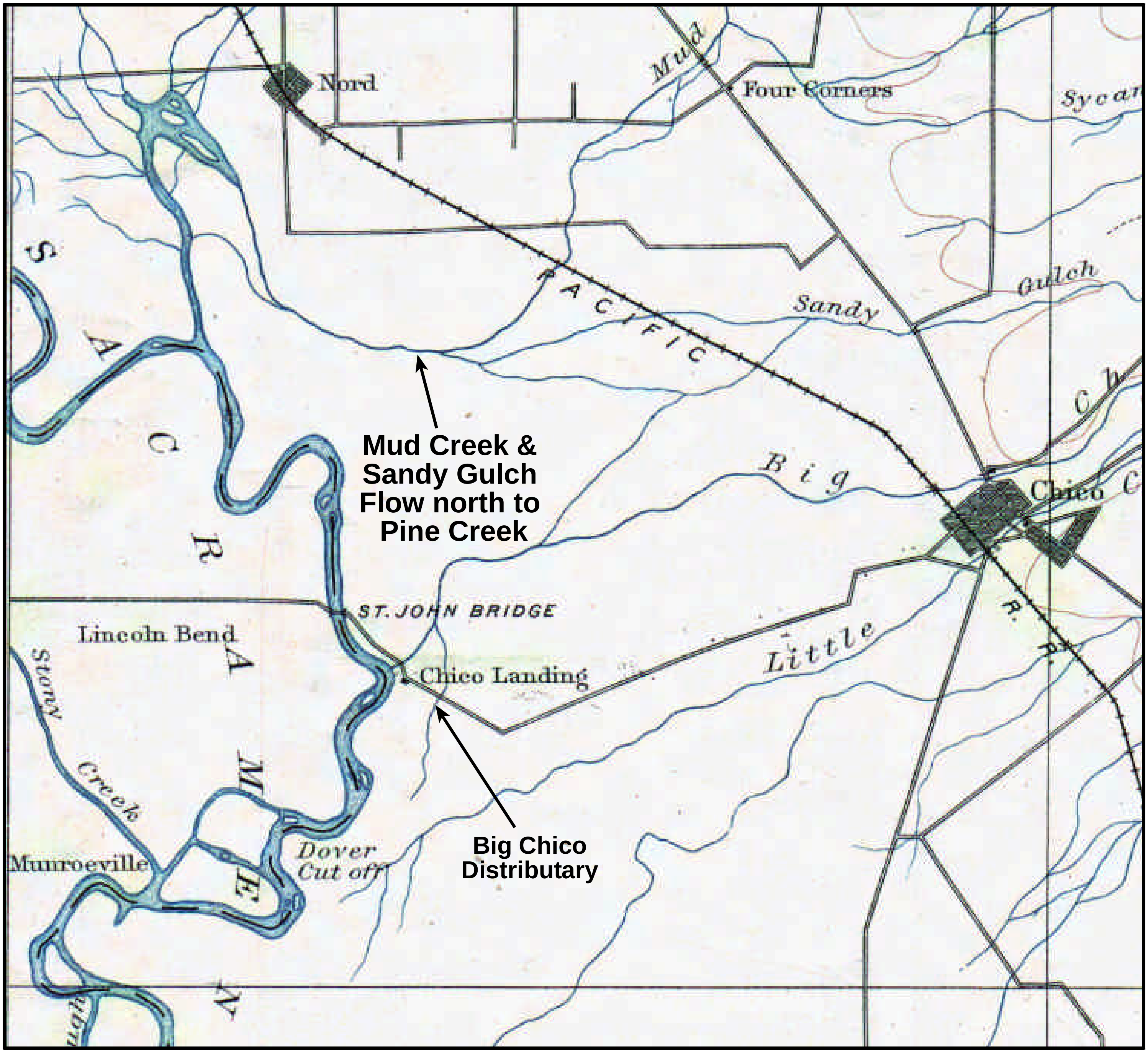


Figure 4. 1895 edition of the USGS "Chico" 30' Quadrangle, printed in 1920. Surveying for this map was undertaken from 1886 through 1888. Note the distributary channel from Big Chico Creek, and how Mud Creek and Sandy Gulch run north to Pine Creek/Bosqueo Basin.

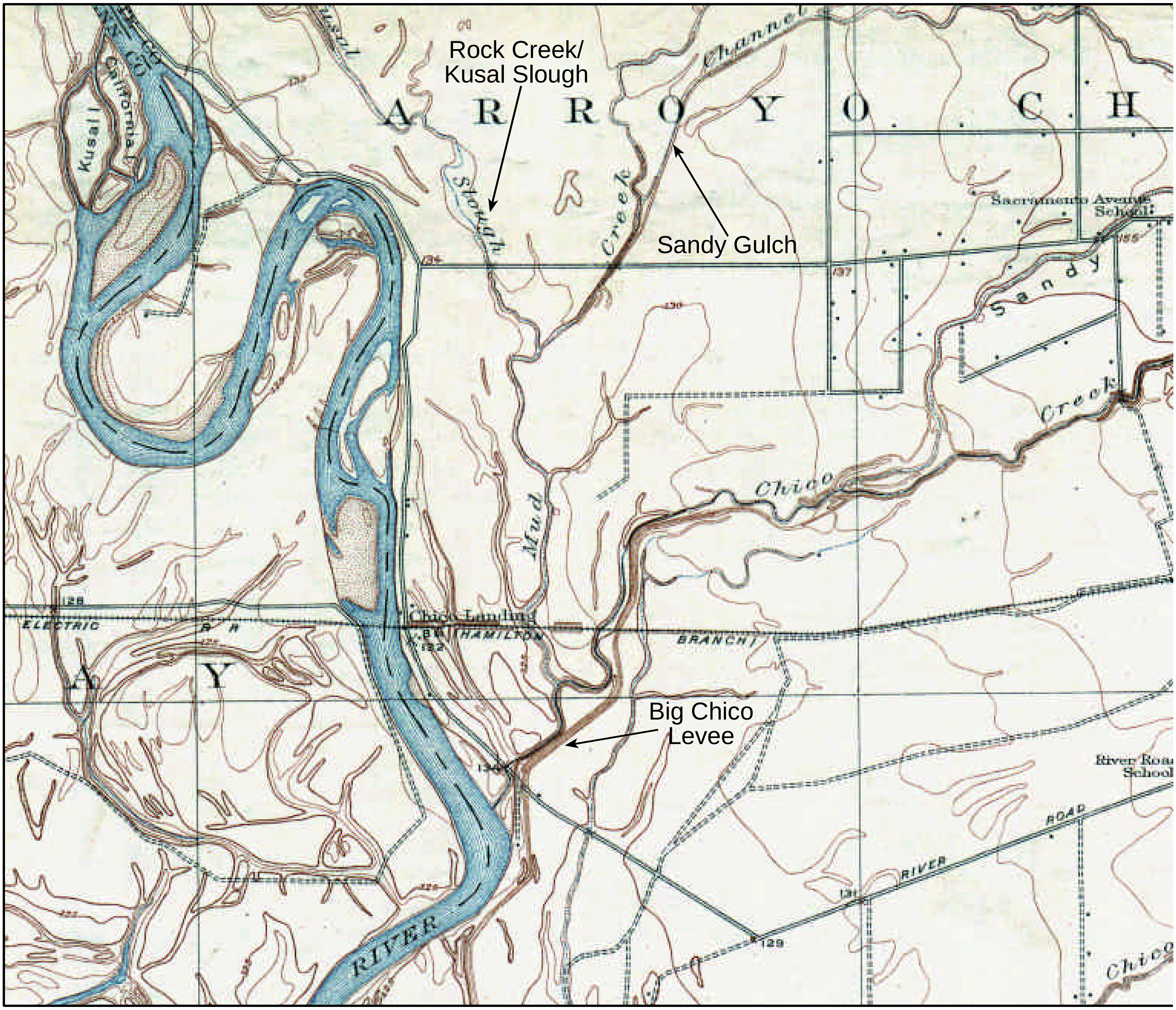


Figure 5. 1912 Edition of the USGS "Chico Landing" 7.5' Quadrangle, surveyed in 1904 and 1910; reprinted in 1931. Note how Mud Creek now joins Big Chico Creek upstream of its confluence with the Sacramento River. Rock Creek/Kusal Slough now flows south to join Mud Creek, as does Sandy Gulch, a stream that now flows through a single, straightened channel. The levee along the left bank of Big Chico Creek was constructed between 1904 and 1909, eliminating the distributary from this channel. The Hamilton Branch of the Northern Electric Railroad is visible running along the northern boundary of what is now the Signh parcel.

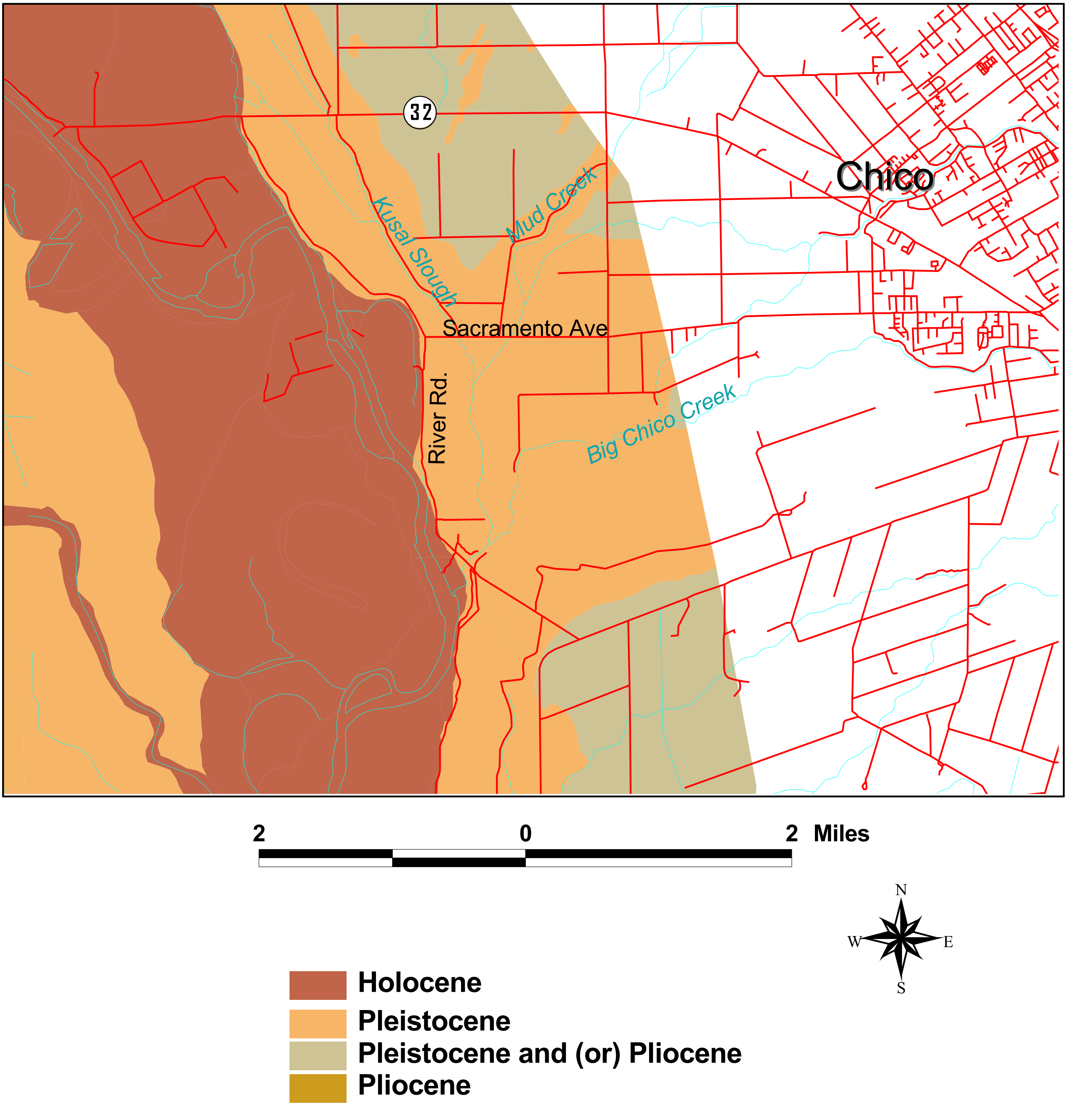


Figure 6a: Map depicting the geologic period in which various surfaces were formed in the study area and surrounding lands. Note that alluvial fan is of Pliestocene age, and older flood basins date from the Pliocene (though they were also actively formed during the Pliestocene as well). Source: DWR, 2001.

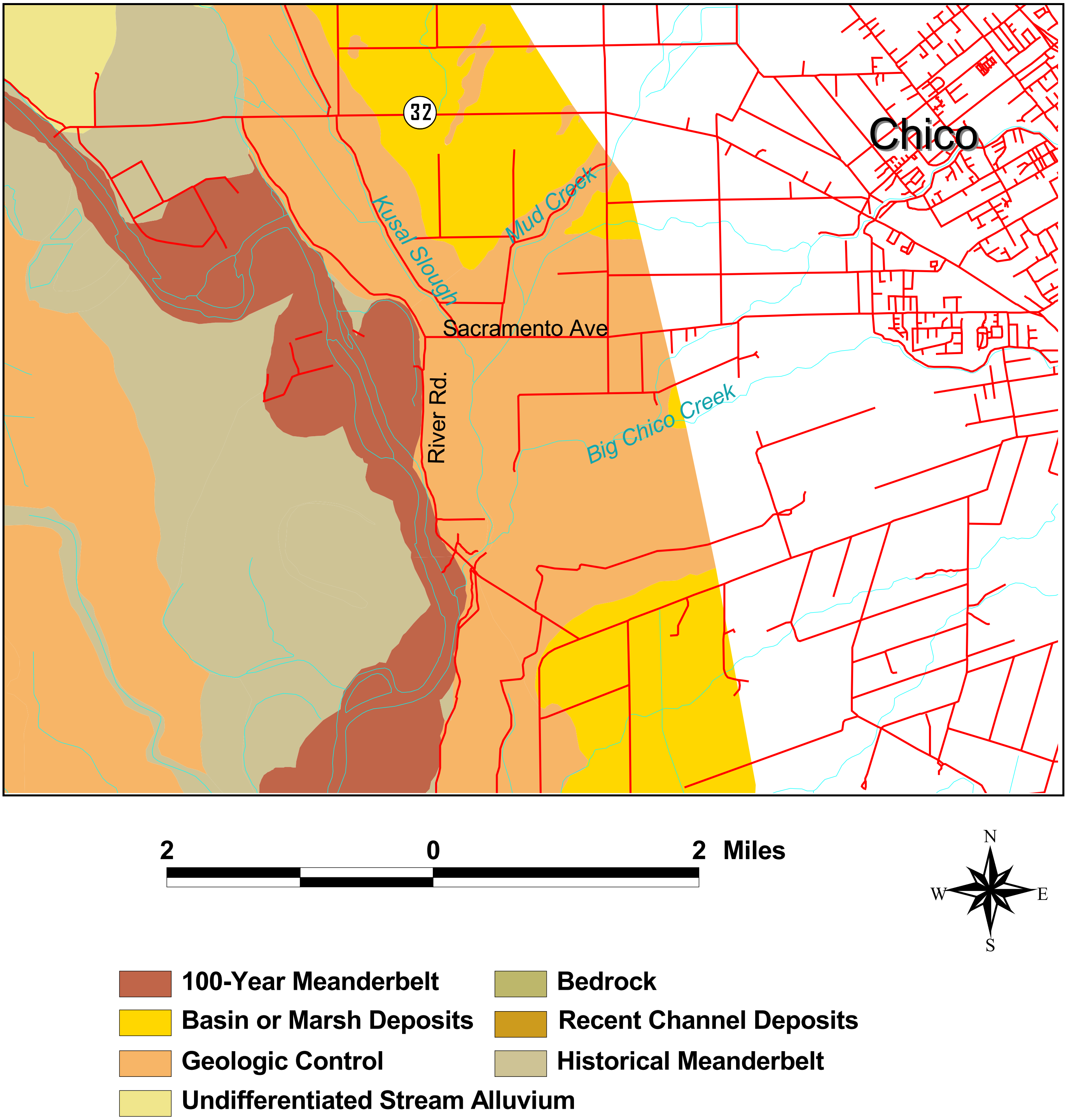


Figure 6b: Map depicting the general surface geology along the river in the vicinity of the study area. Note that the 100-year meanderbelt and historic meanderbelt are constricted on the right bank by the geologic control exerted by the alluvial fan. Source: DWR, 2001.

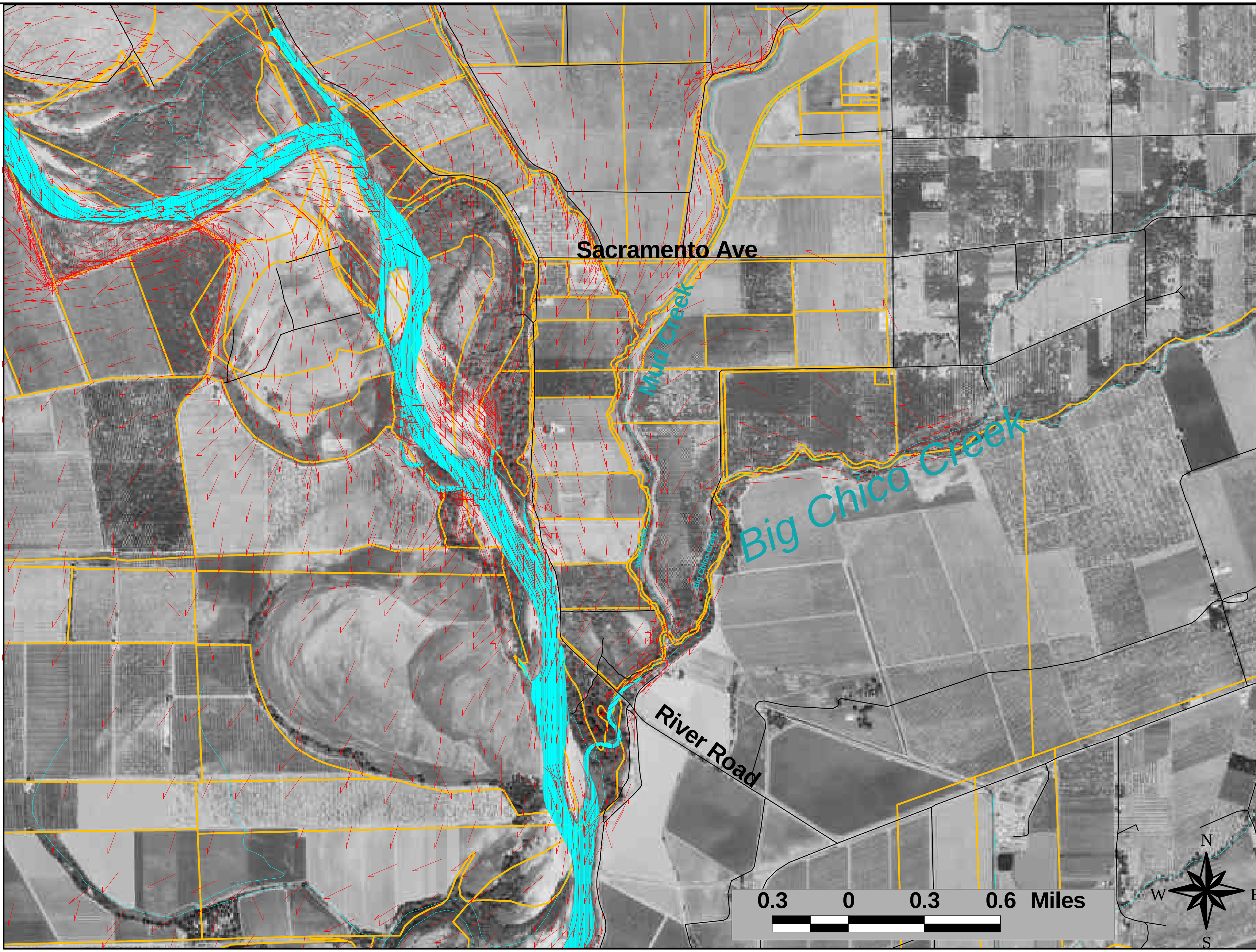


Figure 7: Flow direction and relative velocity are depicted by red scalar vector arrows on this map, expressing the results of 2-dimentional hydraulic modeling efforts (Q=170k cfs for the Sacramento River, 15k cfs for Stony Creek, and 10k cfs for Big Chico Creek). Note how flows north of Sacramento Avenue (in the Bosquejo Basin) return to the river through the study area. Source: TNC, 2001b.

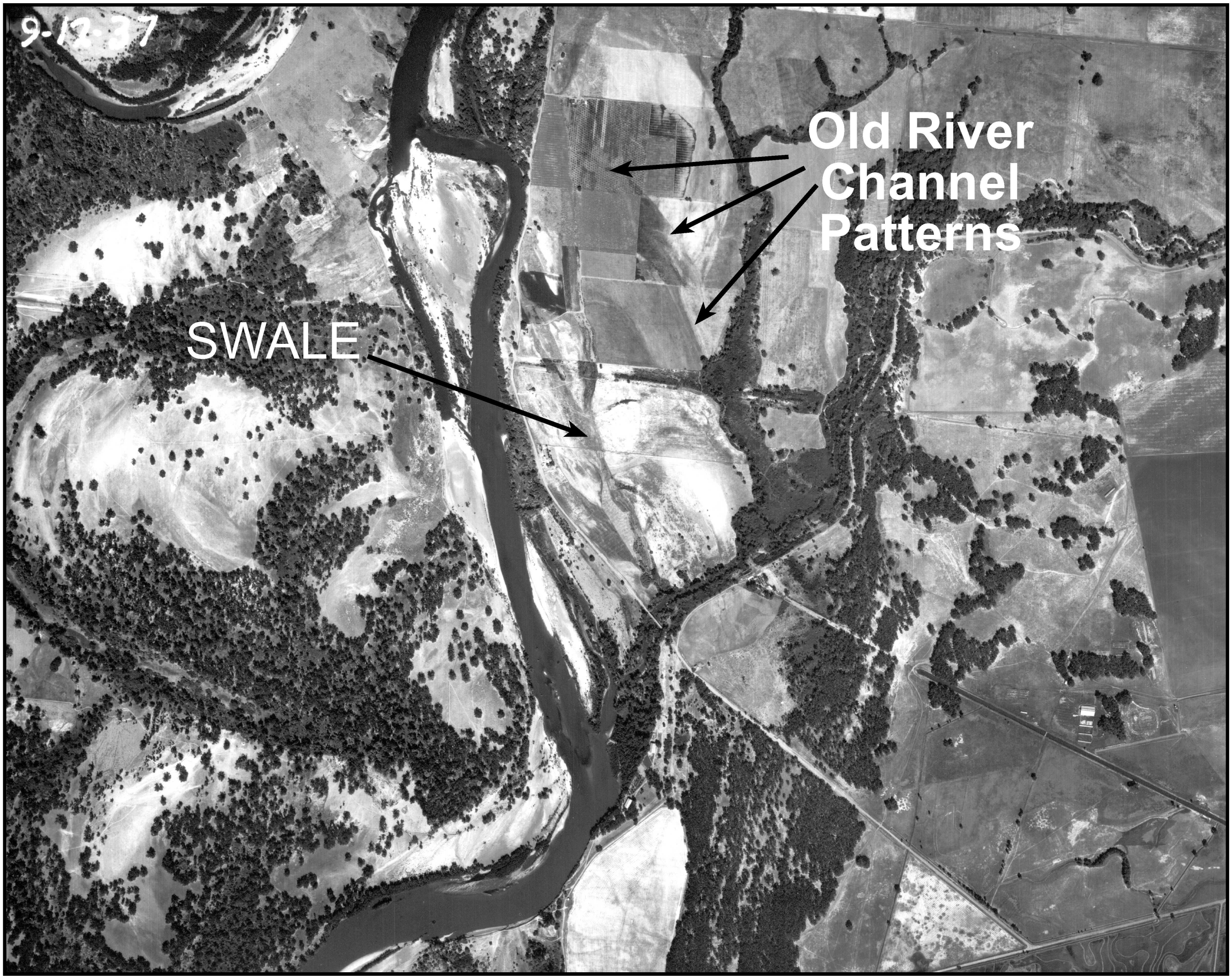
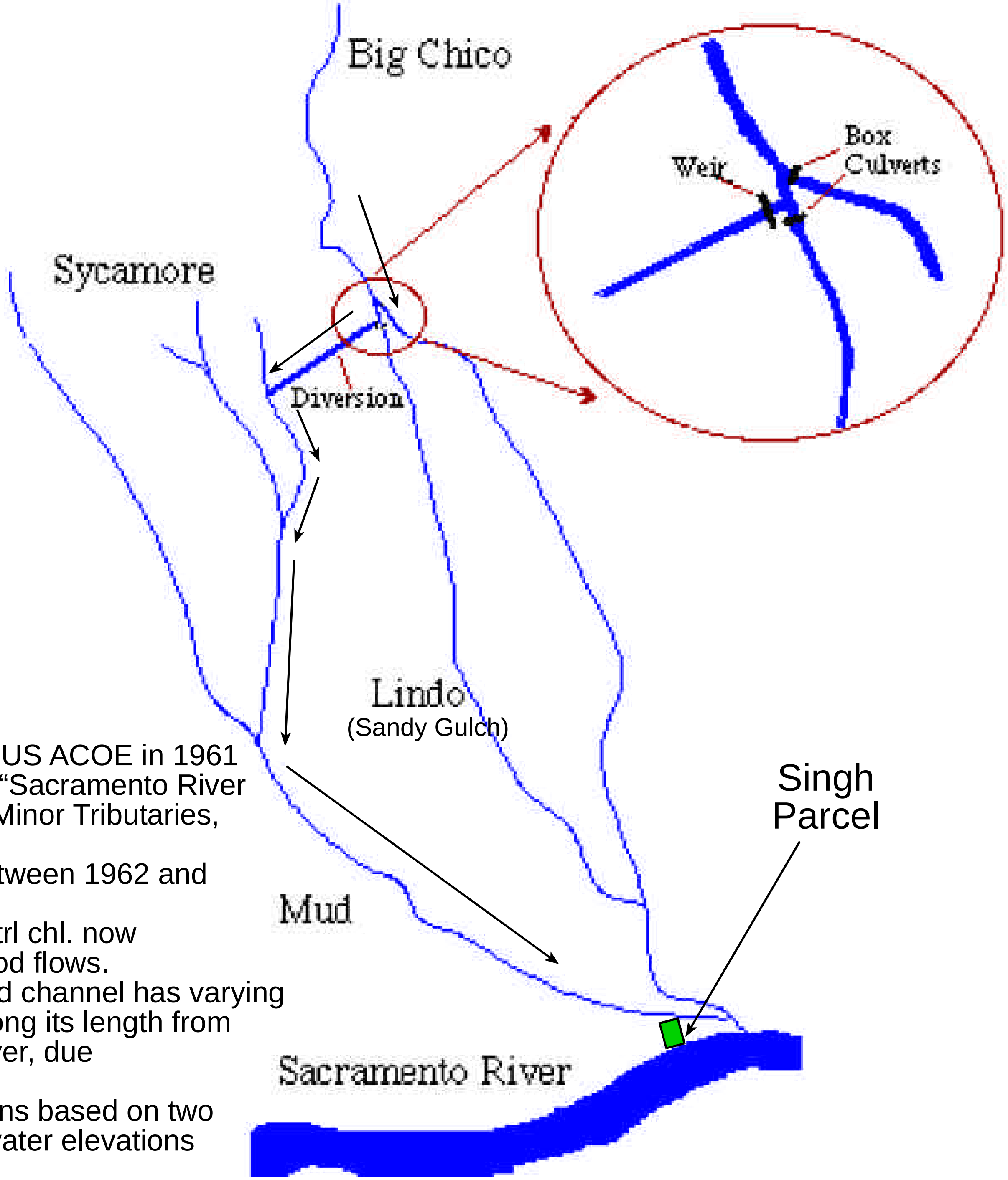
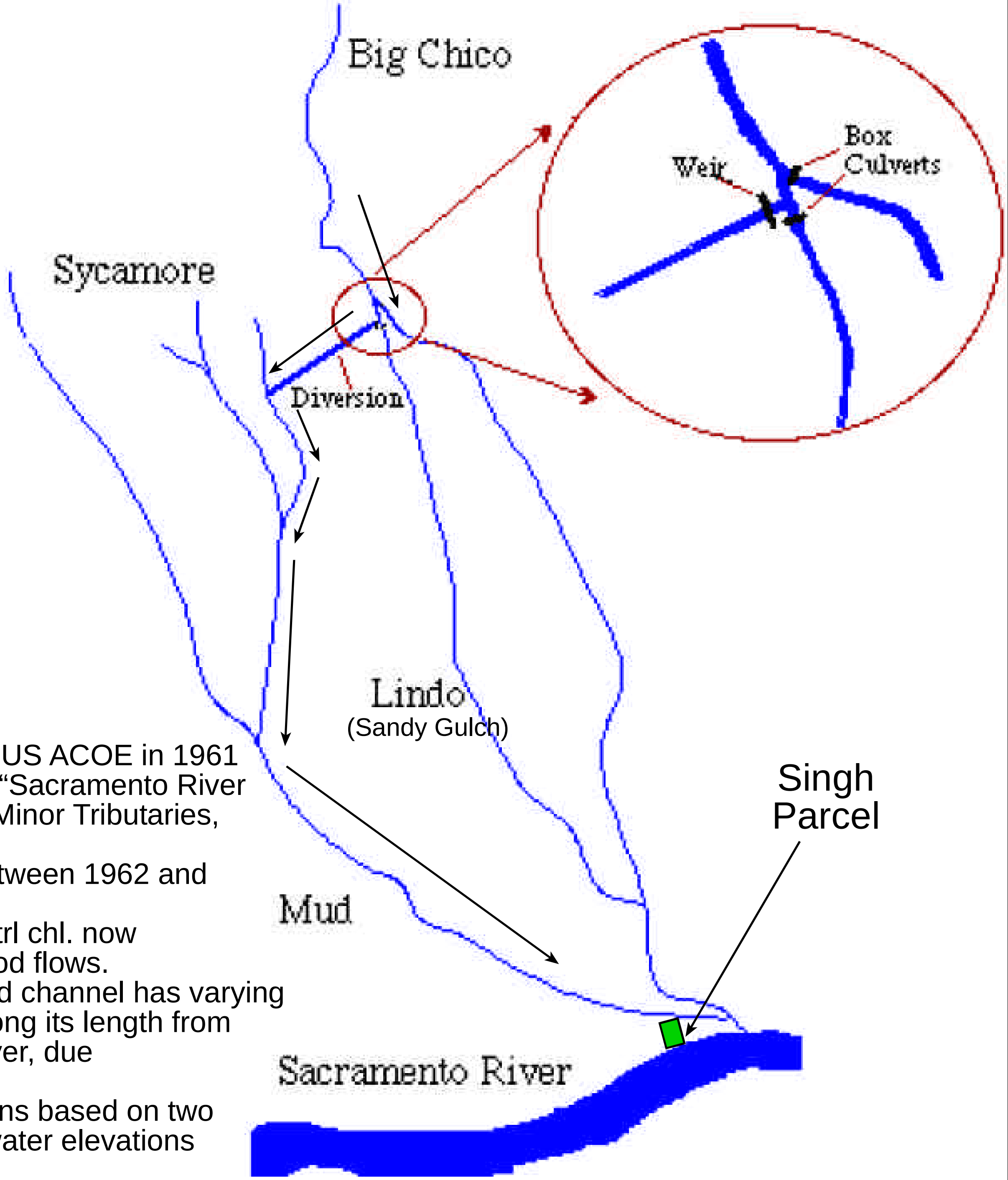


Figure 8: Historic aerial photograph of study area, courtesy of DWR (2001). Note the distinct swale feature near the river, which is still intact today. To the north, note the shape and location of the old channel patterns. Historically, the river likely flowed along this channel pattern and down through the area occupied by Mud Creek during the time of this photograph.



- Planned by the US ACOE in 1961 as a part of the “Sacramento River and Major and Minor Tributaries, California.”
- Constructed between 1962 and 1964.
- Mud Cr. flood ctrl chl. now carries BCC flood flows.
- Mud Creek flood channel has varying design flows along its length from Chico to the River, due to costs (RR).
- Hydraulic designs based on two different flood water elevations of the River.
- Mud Cr. channel in Study Area was to be constructed to a width of 80 feet across channel bottom.

Figure 10: Adapted from Dr. Paul Maslin’s CSUC website. Arrows along the channel indicate how Big Chico Creek floodwaters are shunted to Mud Creek.



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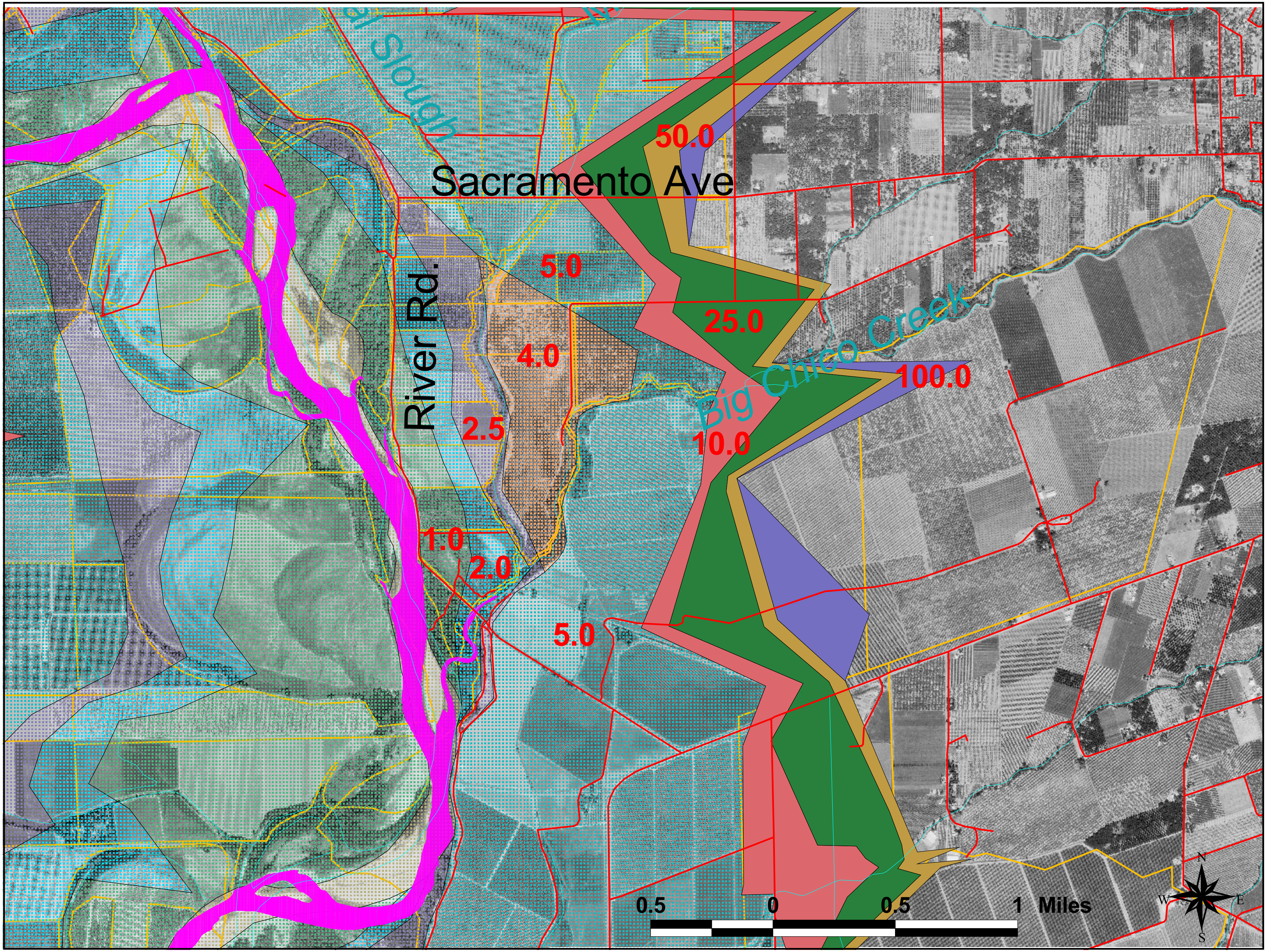

Figure 11: Map depicting flood recurrence periods for lands in the study area. The 2.5-year recurrence level is based on photographs of an actual 2.5-year flood, making it perhaps the most reliable. Note that this level flood inundates most of the study area west of Mud Creek. Source: DWR, 2001.

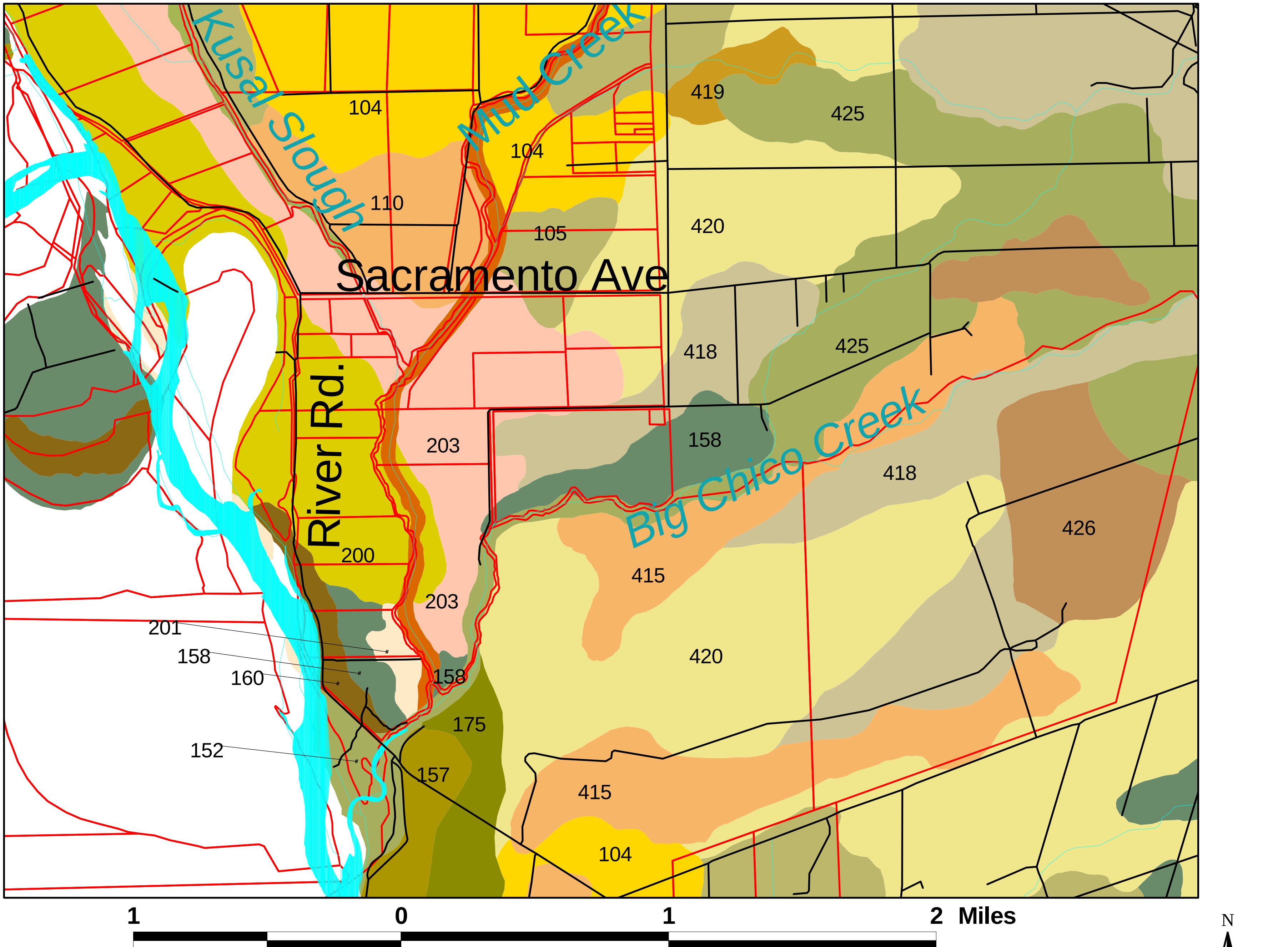

Figure 12: Map depicting preliminary map units for soils surveyed by the NRCS Butte County Soil Survey. Soil map units (identified by numbers on the map) are described in detail in Appendix C). Soils in the area of the Singh parcel are highly varied due to depostional patterns of the river in this area of active channel migration. Souce: DWR, 2001.

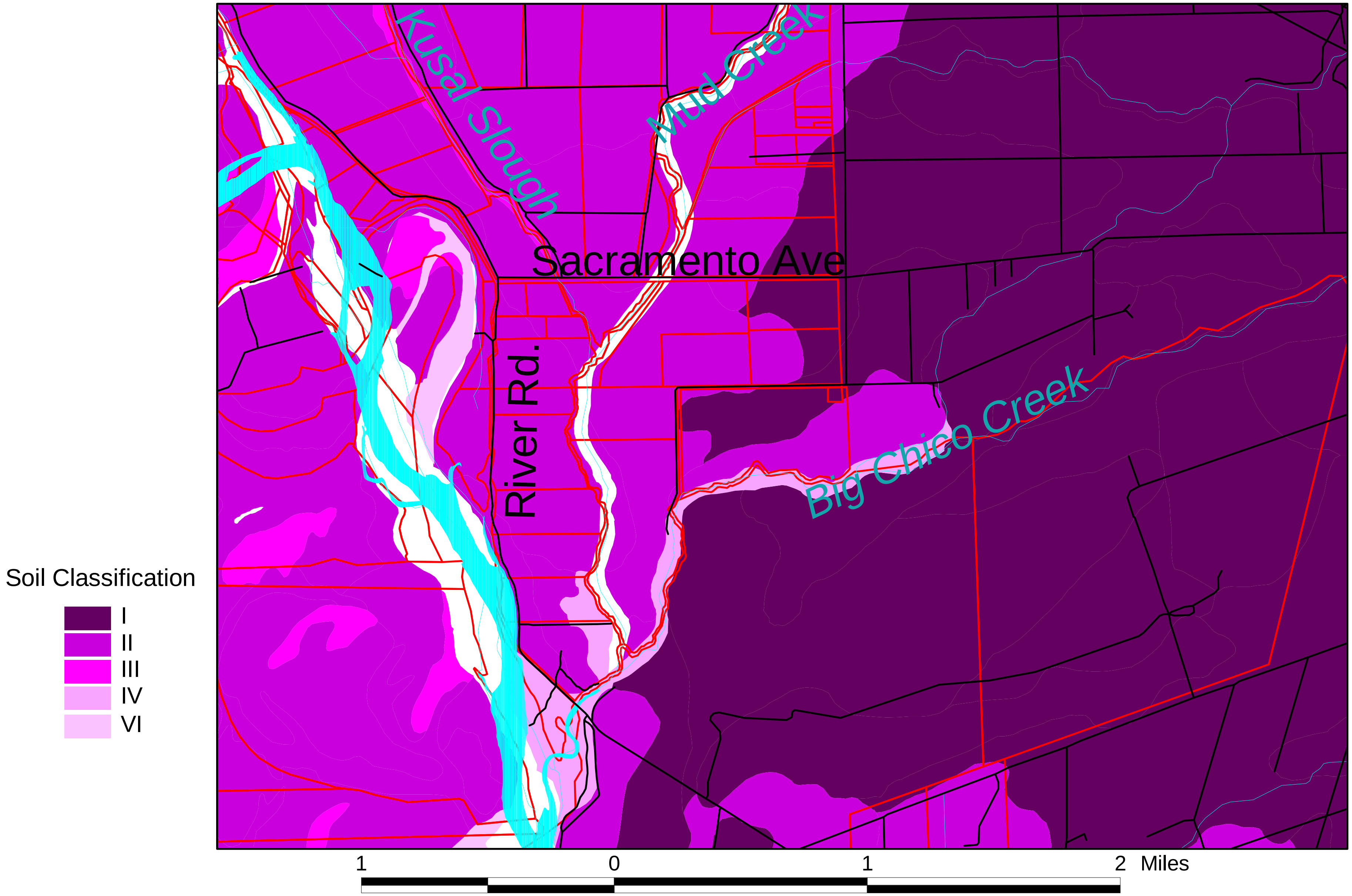

Figure 13: Map depicting land capability classification. This is a classification sysem based on factors such as whether the land is irrigated (or not), its surface layer soil texture, permeability, avialable water, depth to water table, slope and whether it floods or not. Note that soils in vicinity of study area are of lower capability than soils less-frequently flooded further up the fan, though other factors are involved in their increased capability. Source: DWR, 2001; NRCS Chico Soils Office, 2001.

Figure 14: Well established riparian habitat along the banks of Big Chico Creek just upstream of its confluence with the Sacramento River. This physical location was, some 70 years ago, “river channel,” but subsequent to channel migration and sediment deposition by the creek and the river, this area now supports relatively mature riparian vegetation.

Figure 15: Photograph looking upstream on Big Chico Creek. The bridge, constructed in the Fall of 2000, carries River Road over Big Chico Creek.

Figure 16: Photograph taken looking upstream in the channel of Mud Creek.

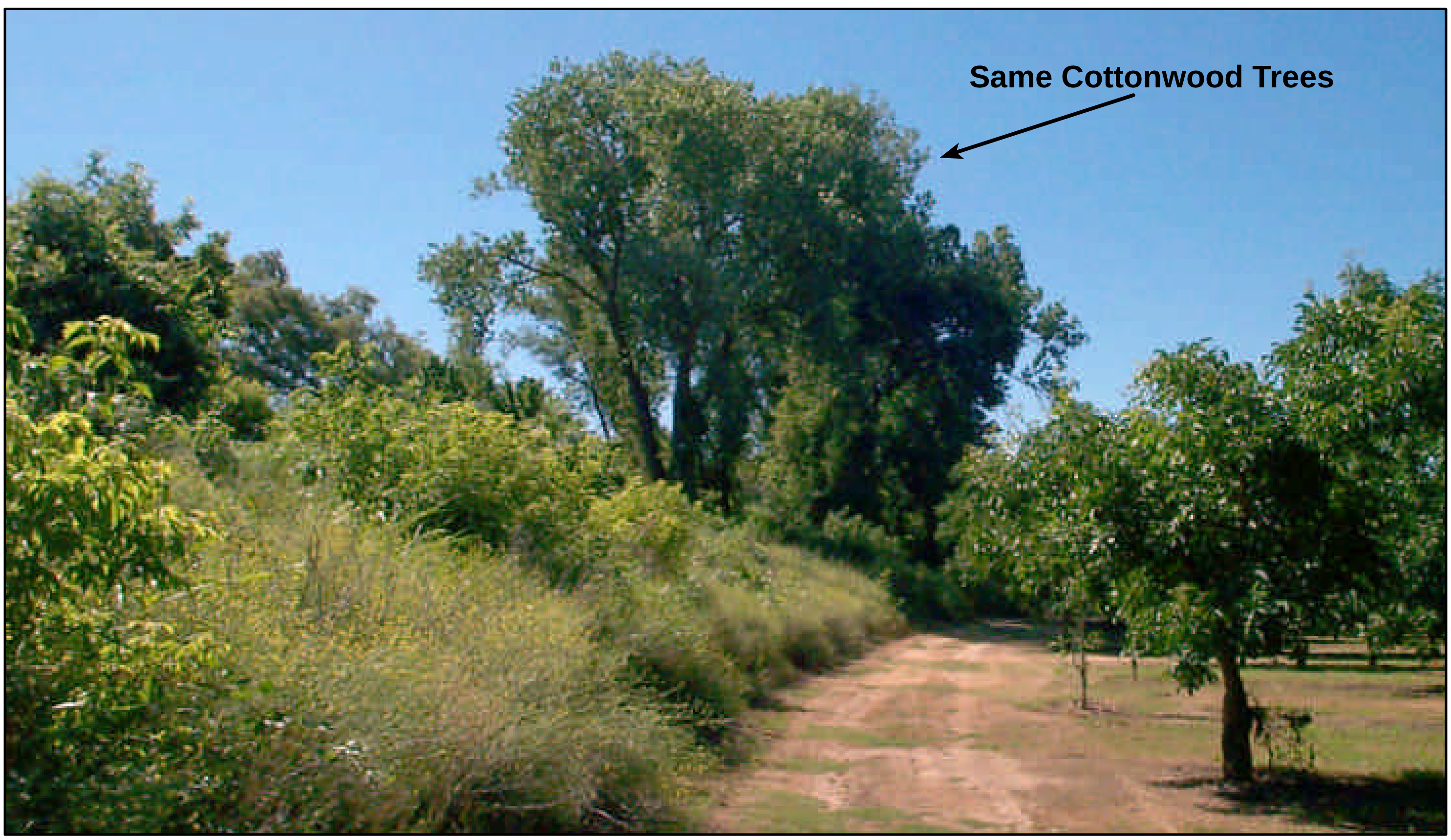

Figure 17: Top Photograph--Oblique aerial photograph looking upstream on Mud Creek; note location of trees relative to lower photgraph. Lower Photograph--Looking downstream along the right (west) bank of Mud Creek; note the location of trees from aerial photograph. Berm appears to be composed of flood debris and soils from the orchards and is covered in stall thistle in this area.

Figure 18: Upper Photograph--view looking out of swale, in a downstream direction, toward the Peterson Addition. Lower Photograph--View looking downstream back into swale. Person in swale is located just downstream of where the upper photo was taken. Note well established vegetation in the swale on the Peterson Addition, downstream of Singh.

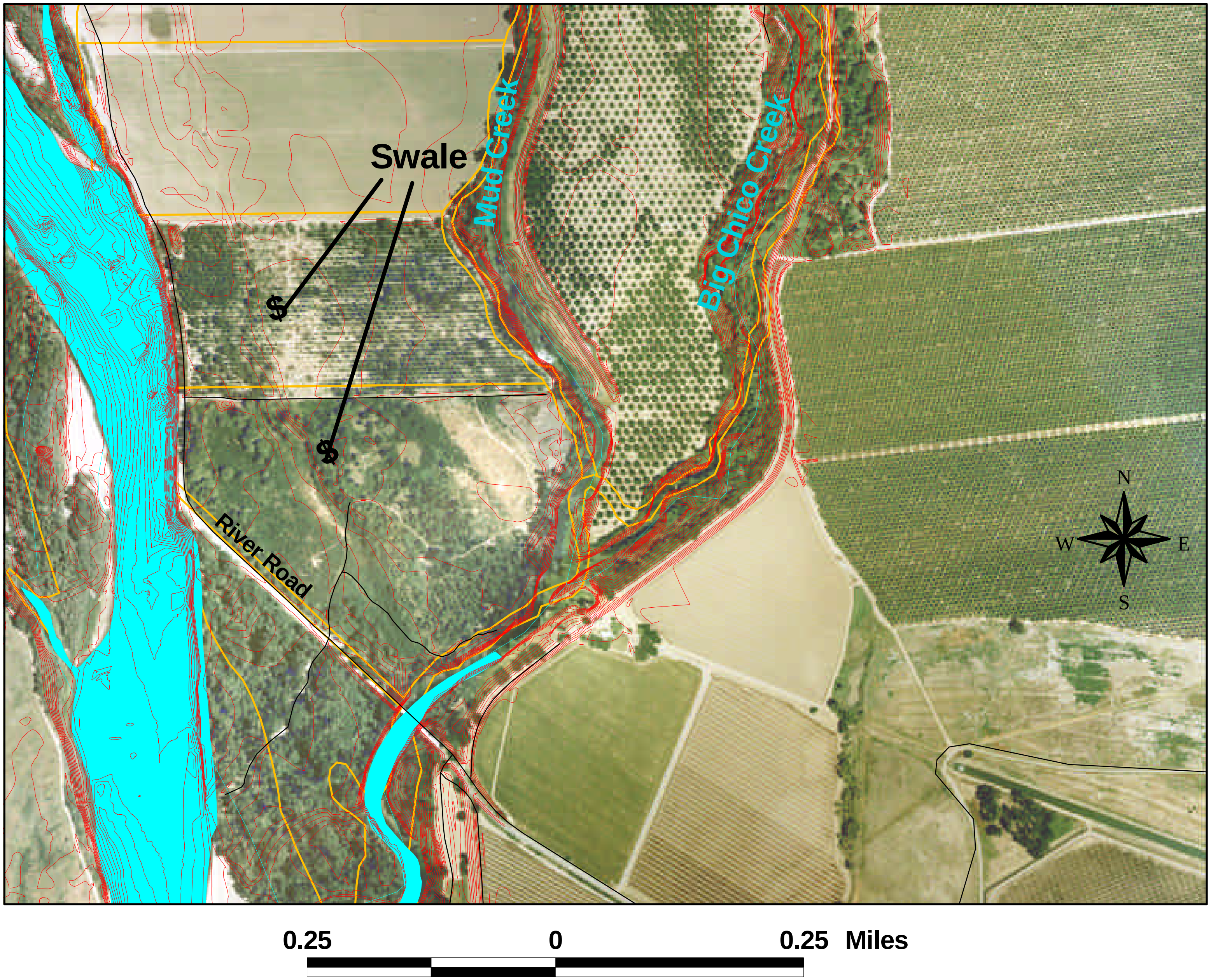

Figure 19a: Map depicting topographic data for portions of the study area. Contour interval is two feet. Note the swale (possibly a remnant distributary channel of the river) that runs through the entire Singh parcel, and connects to Big Chico Creek. Source: ACOE Comprehensive Study Data (via CSUC, GIC, 2001).

Figure 19b: Oblique aerial photograph showing approximate location of swale (indicated with green dashed line) through the Singh parcel and the Peterson Addition.

Figure 20: Dr. Paul Maslin has sampled juvenile salmonids in many locations in and around the study area. “X”s mark some of the locations sampled; note that some sites may appear as “terrestrial” habitat during times of summer flow, such as that shown here. To the north of the study area, water flowing out of the river during times of flood, flows through the study area, then heads back into the river (indicated with black arrows). This likely accounts for the remnant quality of the area as floodplain habitat for juvenile salmonids and other fish.

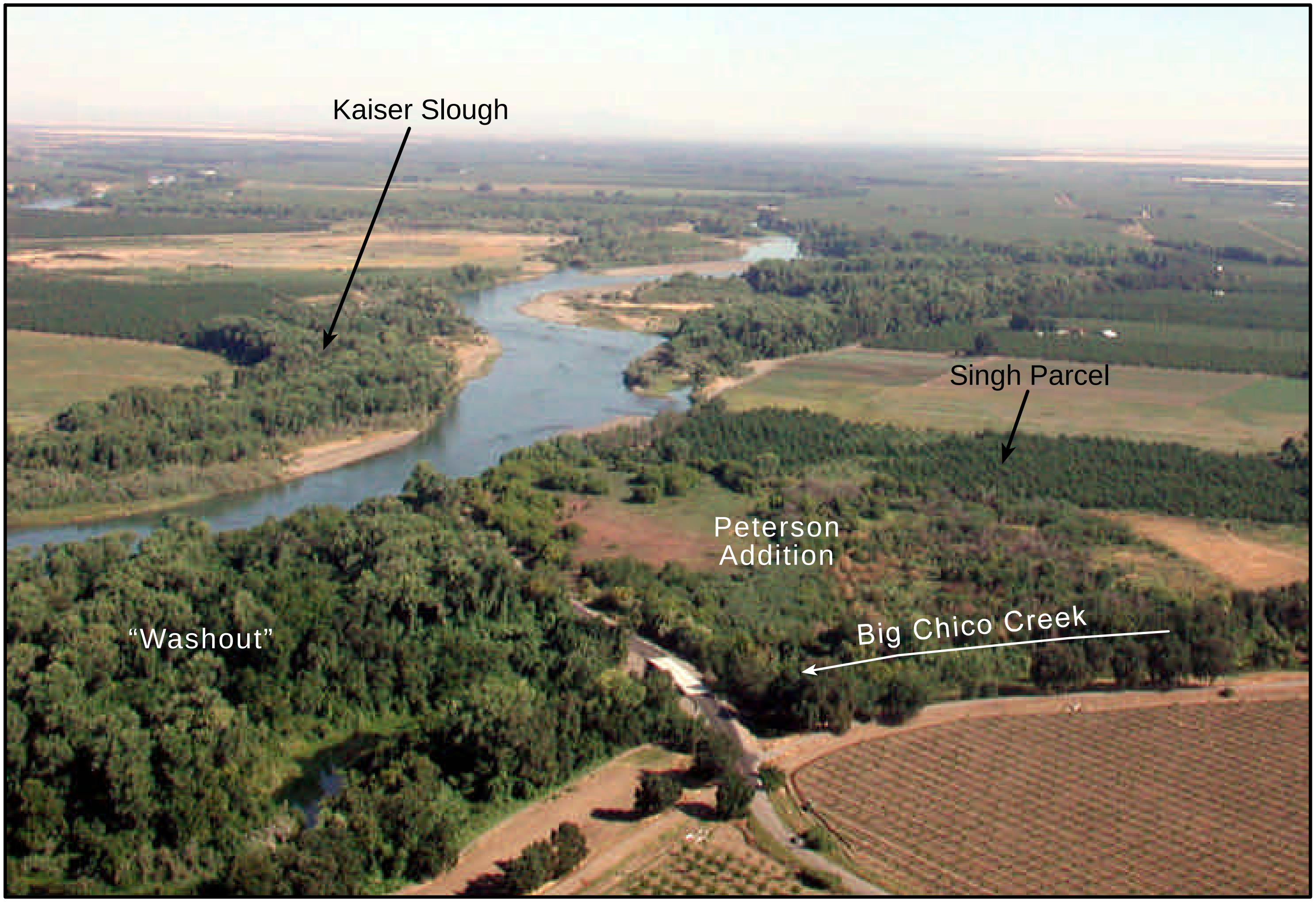

Figure 21. The Kaiser Slough Unit of the Sacramento River National Wildlife Refuge is located directly across the river from the Singh parcel and California State Parks' "Peterson Addition" and "Washout" natural areas. Restoration of the Singh parcel and other adjoining properites would create a significant extent of contiguous riparian habitat.

Appendix B: Detailed Property Description For Parcels In Study Area

Singh

This approximately forty-acre floodprone property is located along the east bank of the Sacramento River, immediately east of River Road and approximately one-half mile north of Big Chico Creek. The property has historic channel topography and existing shaded riverine aquatic habitat along Mud Creek. The property is bordered by River Road on the west, Mud Creek on the east, the Bidwell-Sacramento River State Park on the south, and private fallow farmland to the north. According to a GPS survey, approximately thirty-four acres of the property are planted to walnuts, ranging in age from one-year replants to ten-year old trees.

Nock

This approximately 125-acre floodprone property is located to the east of the Sacramento River, at the confluence of Mud Creek and Big Chico Creek. The property has existing shaded riverine aquatic habitat along Mud Creek and Big Chico Creek. This triangular-shaped property is bordered by Mud Creek on the west, Big Chico Creek on the east, and a private orchard to the north. Approximately 103 acres of the property are planted to walnuts, with twenty-five acres planted in 1974 and the remaining seventy-eight acres planted in 1984. In addition, some seedlings were planted in 1997 to fill in holes in the orchard created by the growth pattern.

Nicholas

This approximately 146-acre floodprone property is located along the east bank of the Sacramento River, immediately east of River Road and approximately two miles north of Big Chico Creek. The property has historic channel topography and existing shaded riverine aquatic habitat along Mud Creek. The property is bordered by River Road on the west, Mud Creek on the east, private row crop farmland on the south, and a private orchard to the north. Approximately 104 acres of the property are planted to walnuts, ranging in age from six-year old trees to eleven-year old trees. The property also contains a thirty-two acre almond orchard, planted approximately ten years ago.

Appendix C: Soil Descriptions

Natural Resources Conservation Service
Butte County Soil Survey 612
--Draft Information--

104 = BOSQUEJO CLAY, 0 to 2 percent slopes; somewhat poorly drained; ponded runoff for very brief to brief duration; low permeability. The soils are occasionally flooded for brief duration from December through March. Soil is very deep, somewhat poorly drained soils that formed in alluvium weathered from basic igneous rocks. Bosquejo soils are in interfan basins. This soil is used for grain, alfalfa, sugarbeets, sunflowers, and safflower, and less often for prune and almond orchards. Natural vegetation was annual and perennial grasses and forbs (including tules).

105 = BUSACCA CLAY LOAM, 0 to 1 percent slopes; moderately well drained; occasionally ponded runoff for brief duration; slow to moderately slow permeability. The soils are rarely flooded for very brief periods from December through March. Ponding can occur at depths of + 3 inches to 0 inches from December through March. Busacca soils are on distal fans. The soil consists of very deep, moderately well drained soils that formed in alluvium from mixed sources. This is soil is used for pasture, row crops and some orchards.

110 = BOSQUEJO SILT LOAM, 0 to 2 percent slopes, overwash, *occasionally flooded*, somewhat poorly drained; ponded runoff for very brief to brief duration; low permeability. The soils are occasionally flooded for brief duration from December through March. Soil is very deep, somewhat poorly drained soils that formed in alluvium weathered from basic igneous rocks. Bosquejo soils are in interfan basins. This soil is used for grain, alfalfa, sugarbeets, sunflowers, and safflower, and less often for prune and almond orchards. Natural vegetation was annual and perennial grasses and forbs (including tules). Silty overwash derived from flood deposits deposited over basin materials.

152 = MAYWOOD FINE SANDY LOAM, 0 to 2 percent slopes, *frequently flooded*. Well-drained, very deep flood plain soils formed from alluvium deposited by the Sacramento River. Vegetation consists of agricultural varieties and natural vegetation including valley oaks, cottonwood, grasses and forbs.

157 = MAYWOOD FINE SANDY LOAM, 0 to 2 percent slopes, *occasionally flooded*. Well-drained, very deep flood plain soils formed from alluvium weathered from mixed rock sources and deposited by the Sacramento River. Vegetation consists of agricultural varieties and natural vegetation including valley oaks, cottonwood, and grasses and forbs.

158 = GIANELLA FINE SANDY LOAM, 0 to 2 percent slopes, *occasionally flooded*. Well-drained, very deep flood plain soils formed of alluvium from mixed sources deposited by the Sacramento River. Vegetation consists mostly of orchards, but natural

vegetation including valley oaks, cottonwood, wild grape, blackberries, annual grasses and forbs may exist in patches and or along waterways.

160 = GIANELLA LOAM, 0 to 2 percent slopes, *occasionally flooded*. Well-drained, very deep flood plain soils formed of alluvium from mixed sources deposited by the Sacramento River and located along the meander belt. Vegetation consists of orchard varieties and natural vegetation including valley oaks, cottonwood, and grasses and forbs.

200 = HORST SILT LOAM, 0 to 2 percent slopes, *occasionally flooded*. Well-drained, very deep flood plain soils formed of alluvium from mixed sources deposited by the Sacramento River. Vegetation consists mostly of agricultural varieties but natural vegetation including valley oaks, cottonwood, blackberries, California wild grape, poison oak, annual grasses and forbs.

201 = HORST SILT LOAM, 0 to 2 percent slopes, *frequently flooded*. Well-drained, very deep flood plain soils formed of alluvium from mixed sources deposited by the Sacramento River. Vegetation consists mostly of agricultural varieties but natural vegetation including valley oaks, cottonwood, blackberries, California wild grape, poison oak, annual grasses and forbs.

203 = KUSAL SILTY CLAY LOAM, 0 to 2 percent slopes, *occasionally flooded*. Somewhat poorly drained, very deep flood plain soils formed of alluvium derived from mixed sources deposited by the Sacramento River. Kusal soils are on flood plains and lack intersecting slickensides, do not crack, and formed from flood deposits deposited over basin materials. Vegetation consists mostly of orchard varieties, but natural vegetation including valley oaks, cottonwood, blackberries, poison oak, California wild grape, annual grasses and forbs may be found in patches and or along waterways.

415 = IGNORD FINE SANDY LOAM, 0 to 2 percent slopes, well-drained; moderately rapid permeability. Occurs on distal ends of alluvial fans, on low ridges and mounds. These soils formed in alluvium weathered from mixed sources. They are on slightly higher positions than the surrounding soils, and they have been extensively modified and leveled for agriculture. Native vegetation was grasses and valley oak woodland. This soil currently is used for row crops, grain, and orchards.

418 = CONEJO LOAM, 0 to 2 percent slopes, well-drained; slow to medium runoff, moderately slow permeability. Some areas are subject to occasional flooding. Conejo loam is located on the proximal end of alluvial fans and fingers down-fan along stream terraces. They are very deep, well drained soils that formed in alluvium from basic igneous or sedimentary rocks. Native vegetation is annual grasses and forbs with few scattered oaks. Currently used for irrigated row crops, orchard, hay and pasture and grain.

420 = CONEJO CLAY LOAM, 0 to 2 percent slopes, well-drained; slow to medium runoff, moderately slow permeability. Some areas are subject to occasional flooding.

Conejo clay loam is located on the distal end of alluvial fans and along some stream terraces. They are very deep, well drained soils that formed in alluvium from basic igneous or sedimentary rocks. Native vegetation is annual grasses and forbs with few scattered oaks. Currently used for irrigated row crops, orchard, hay and pasture and grain.

425 = VINA FINE SANDY LOAM 0 to 2 percent slopes, well-drained; slow or medium runoff; moderate permeability; *occasionally flooded*. These soils are very deep, well-drained soils on alluvial fans and flood plains. Currently used for irrigated row crops, orchards, hay, and pasture. Vegetation includes valley oaks, cottonwoods, annual and perennial grasses.

990 = RIVERWASH
This unit consists of un-stabilized, recent alluvial deposits of stratified sandy, silty, gravelly or cobbly sediments that are reworked by water almost every year. No permanent vegetation exists here due to flooding and churning of the components.

Appendix D: Avian Species List

Species list, by habitat, of birds observed on our site visit to the Singh Property on the morning of July 16, 2001.

Walnut Orchard	**Riparian (Mud Creek)**	**Field**
American Robin	American Goldfinch	Lark Sparrow
California Towhee (in brushpile	American Robin	Black Phoebe
House Finch	Black-chinned Hummingbird	Brown-headed Cowbird
Nuttall’s Woodpecker	Black-headed Grosbeak	Tree Swallow (family)
Lark Sparrow	Brown-headed Cowbird	
Lesser Goldfinch	Bullock’s Oriole	
Western Bluebird (family)	California Quail	
Western Kingbird	Common Yellowthroat	
Western Wood Pewee	House Wren	
	Lazuli Bunting	
	Nuttall’s Woodpecker	
	Peahen & chicks	
	Spotted Towhee	
	Western Kingbird	
	White-breasted Nuthatch	

Also heard calling from the adjacent Peterson Addition include: Ash-throated Flycatcher, Brown-headed Cowbird, California Towhee, Spotted Towhee, Lazuli Bunting.

Appendix E: Historic Maps "On-Line"

List of relevant maps available on the World Wide Web:

To link to these files please use the following URLs...
http://maps.csuchico.edu/cgi-bin/find.cgi?find=ca_737.sid
http://maps.csuchico.edu/cgi-bin/find.cgi?find=ca_780.sid
http://maps.csuchico.edu/cgi-bin/find.cgi?find=ca_773.sid
http://maps.csuchico.edu/cgi-bin/find.cgi?find=ca_51.sid
http://maps.csuchico.edu/cgi-bin/find.cgi?find=ca_67.sid
http://maps.csuchico.edu/cgi-bin/find.cgi?find=ca_855.sid
http://maps.csuchico.edu/cgi-bin/find.cgi?find=ca_856.sid

Appendix F: GIS Metadata

The coverages utilized in the GIS created for this project (including certain figures in the report) were attained from three sources: the California Department of Water Resources-Northern District; the Geographical Information Center, California State University, Chico; and The Nature Conservancy Sacramento River Project. The metadata or information to obtain the metadata for coverages attained from each source are listed below:

CALIFORNIA STATE UNIVERSITY, CHICO
GEOGRAPHICAL INFORMATION CENTER (GIC)
SACRAMENTO RIVER RIPARIAN VEGETATION COVERAGE DRAFT METADATA
February, 2000

NOTES TO USERS: By accepting this Sacramento River Riparian Vegetation (SRRV) GIS data, the user agrees to the following terms:

* Interested parties please contact the Director of Geographical Information Center, California State University, Chico, Chico, CA, 95929-0425, (530) 898-5969,
email:cwnelson@csuchico.edu
* Graphic or textual representations of this data shall include appropriate references to the source, authors, and agencies.
* The data shall not be amended, edited, or revised, nor shall it be used inappropriately to produce inaccurate, incomplete, or misleading analyses, reports, or maps.

PROJECT NAME: Sacramento River Riparian Mapping

PROJECT COORDINATORS: Chuck Nelson, Geographical Information Center, California State University, Chico; Stacey Cepello, California Department of Water Resources - Northern District; and Jim Nelson, Craig Martz, and John Seperek, California Department of Fish and Game - Region 1.

LAYER NAMES:
nvriparian

DESCRIPTION:
The Sacramento River Riparian Mapping Project developed to inventory and map riparian lands along the Sacramento River and its major tributaries. The study area was confined to streams in the Sacramento Valley, CA. and mapping ended in the foothill canyons on both sides of the Valley.

The project was funded in four phases. Phase 1 included southern Shasta County and was funded using 1086 money from the Department of Water Resources (DWR). Phase 2 included Tehama County and was also funded by DWR. Phase 3 included Butte County and was a joint effort by DWR and the U.S. Bureau of Reclamation. Phase 4 included the Sacramento River mainstem to Suisun Bay, the Feather, American, Yuba, and Bear Rivers, Butte Sink, the Sutter Bypass, and Stony, Cache, and Putah Creeks on the west side; funded by a CalFed Category 3 grant.

VITAL STATISTICS

Datum:NAD 27
Projection: Universal Transverse Mercator (UTM)
Units: Meters
Source media: Color infrared aerial photography
Source dates, scales, file size(.shp files only), and no. of data records:

1. Keswick Dam to Tehama County line, 1991, nominal scale RF= 1:9,600, 15.1 Mb., 2398 data records.
2. Tehama County, 1993, nominal scale RF= 1:12,000, 14.7 Mb., 4578 data records.
3. Butte County, Glenn County side of Sacramento River, 1994, nominal scale RF= 1:12,000, 18.3 Mb., 3127 data records.
4. Sacramento River mainstem - Butte County line to American River, 1996, nominal scale of RF= 1:12,000, 1.4 Mb., 717 data records.
5. Lower Stony Creek to Black Butte Dam, 1996, nominal scale RF= 1:12,000, 1.5 Mb., 980 data records.
6. Lower Butte Creek from Butte County line, Butte Sink, 1996,nominal scale RF= 1:12,000, 3.0 Mb., 2050 data records.
7. Sutter Bypass, Butte Slough, 1996, nominal scale RF=1:12,00, sutterbypass 1.52 Mb., 825 data records.
8. Tisdale Weir, 1996, nominal scale RF= 1:12,000, 52.7 Kb., 17 data records.
9. Feather R. from Verona to Butte County line and Yuba R, 1996, nominal scale RF=1:12,000, 3.54 Mb., 1818 data records.
10. Feather River from Butte County line to Oroville, 1997,nominal scale RF= 1:12,000, 1.75 Mb., 958 data records.
11. Yuba R. to Hwy. 20 bridge, 1996, nominal scale RF=1:12,000; 1.0 Mb., 518 data records.
12. Bear River - Feather River to Camp Far West Reservoir, 1996, nominal scale RF= 1:12,000, 737 K., 402 data records.
13. American River - American River to Folsom Lake, 1996, nominal scale RF= 1:12,000, 1.8 Mb., 1191 data records.
14. Sacramento R. from American R. to Suisun Bay,1998, nominal scale RF= 1:12,000, 2.4 Mb., 1257 data records.
15. Cache Creek - Cache Creek from Capay Valley to Yolo Bypass, 1998, nominal scale RF= 1:12,000, 3.1 Mb., 2076 data records.
16. Putah Creek - Putah Creek from Montecello Dam to Yolo Bypass, 1998, nominal scale RF= 1:12,000, 1.2 Mb., 758 data records.
17. Consolidated file, 72.5 Mb., 24,894 data records.

Capture method: Shasta, Tehama, and Butte were hand digitized from mylar overlays of riparian vegetation over airphoto enlargements. Remaining areas were produced from ortho-rectified RF 1:12,000 color infrared scans digitized in ArcView.

Files produced: ArcView shape files

Coverage type: Polygon for vegtype and arcs for stream segments

DESCRIPTION OF RIPARIAN CATEGORIES

BS Blackberry Scrub. >= 80% coverage by blackberry vegetation.

CF Great Valley Cottonwood Riparian Forest. >= 80% Cottonwood by canopy cover - One year old or greater. CF represents the earliest successional sere. These forests are dominated by cottonwood (Populus fremontii) and one or more tree willows (Salix gooddigii variabilis, S. laevigata, and S. lasiandra are most common) California Grape (Vitis californica) is the only conspicuous vine.

EUC Eucalyptus. Eucalyptus globulus. Blue Gum. Found in fairly monospecific stands (one species only)on heavily modified banks. Eucalyptus tends to shade out competitors. NOTE:1998 coverages only.

GR Giant Reed. Arundo donax. Grass <8 meters. A very invasive plant that reduces and replaces native species. NOTE: 1998 coverages only.

HL Herbland Cover. Composed of annual and perennial grasses and forbs. Must be enclosed by riparian vegetation or the stream channel.

M Valley Freshwater Marsh. Valley freshwater marshes are dominated by perennial emergent monocots. Coverage may be very high, approaching 100%. Cattails (Typha spp.) or tule (Scripus spp.) usually are the dominants, often forming monotonous swards that are sparingly punctated with additional taxa such as sedges (Carex spp.), cane (Phragmites australlis), or blue vervain (Verbena hastata).

MF Great Valley Mixed Riparian Forest. In this unit neither willows nor cottonwoods dominate - also contains a mixture of more upland, later successional species that may include valley oak (Quercus lobata) at less than 60% canopy coverage, black walnut (Juglans spp.), ash (Fraxinus latifolia), tree of heaven (Ailanthus altissima), and sycamore (Platanus racemosa).

NL No label. In some of our older maps we used NL to depict non-riparian areas surrounded by riparian types. It was a way to show that the label was not missed. It has been dropped in recent coverages, however.

RS Great Valley Riparian Scrub. Young primary succession

TAM.Tamarisk. "Saltcedar" Tamarix chinensis. Invasive shrub found in open areas along the river. Originally introduced as an ornamental and for erosion control, Tamarisk has become an undesirable weed. Plants spread by seed and cuttings and grow rapidly. NOTE: 1998 coverages only.

VO Valley Oak (Quercus lobata) >= 60% canopy cover - must be contiguous or have longest axis greater than the distance from riparian vegetation.

Habitat types:
D Disturbed. This unit identifies areas that are undergoing major disturbances and are now either completely devoid of riparian vegetation or contain only small remnants of it.

DR Disturbed riparian. This unit identifies a past disturbance, primarily dredge tailings with cottonwoods (Populus fremontii) the dominant species and other riparian vegetation types having established since the disturbance.

G Gravel and Sand Bars - These appear as open, unvegetated areas in air photos, but ground truthing reveals several annual and short-lived perennial species of sun-loving herbs, grasses and suffrutescent subshrubs. The vegetation coverage is less than 50%.

OW Open Water. This mapping unit constitutes water, either standing or moving, and does necessarily imply vegetation.

METHODOLOGY:

- Shasta, Tehama, and Butte County coverages - The Shasta, Tehama, and Butte County coverages are complete since the entire Sacramento River and its tributaries containing significant riparian vegetation are represented. Vegetation types were identified from color infrared airphotos. The vegetation categories were polygoned using color infrared aerial photographs at a scale of RF 1:9600 (Shasta) or RF 1:12,000 (Tehama and Butte) as stereo pairs. Interpreted information was transferred to RF 1:4800horizontally controlled ratio-rectified black and white enlargements. There were 155 enlargements. The vegetation information from each was digitized into a separate coverage and transformed individually (for the best transformation results) to TIGER road and stream maps.

Individual coverages were appended together by their distinct flight line number. Flight line sections were appended to compose the final coverage. While relative accuracy is RF 1:4800, positional accuracy varies. Coverages were controlled to U.S. Bureau of Census TIGER line files that meet USGS 1:24,000 scale accuracy standards in urban areas and 1:100,000 scale standards in rural areas. This means that the position of any TIGER feature has an average error of about 24 feet in urban areas, and about 100 feet in rural areas. Our eventual goal is to improve positional accuracy to 1:24,000 throughout the coverage.

-Remaining coverages - The remaining coverages south of the Butte County line were flown at a scale of RF 1:12,000. Color infrared airphoto prints were scanned and orthorectified using 1:24,000 USGS DEM's and SPOT satellite imagery. Ortho images were brought into ArcView. Vegetation was interpreted and digitized on-screen in ArcView. Unlike Shasta, Butte and Tehama coverages, only the major tributary streams were included.

PETERSON ADDITION RIPARIAN VEGETATION SERIES

AGS - California Annual Grassland

Annual grasses and herbs are dominant in the ground layer; bromes, ryegrassses, oats, mustards, star-thistle, clovers, lupines, and filaree (listed in order of dominance) are present. Emergent shrubs and trees are present. Grass < 1 meter is continuous or open.
Observed Associated Species:
Bromes, bindweed, bunchgrass, bentgrasses, Bermuda grass, jungle- rice, barnyard grass, purple lovegrass, nitgrass, barley, ryegrasses, dallisgrass, Kentucky bluegrass, rabbit's foot grass, johnsongrass, bur chervil, hedge-parsley, horseweed, yellow star-thistle, chicory, western goldenrod, weedy cudweed, gumweed, old-man-of-spring, cocklebur, mustards, Shepherd's purse, clovers, red-stemmed filaree, Klamathweed, mints, pokeweed, plantains, docks, and purple-stemmed jimson-weed.

ALM - Almond

Almond is present in the tree canopy. The dominant tree species are almond and valley oak with Oregon ash and California walnut subdominant.
Observed Associated Species:
Box elder, elderberry, valley oak, pecan, Hinds walnut, red gum, Oregon ash, peach, cherry plum, rose, Himalayan blackberry, California blackberry, arroyo willow, California wild grape, Virgin's bower, and Virginia creeper.

AW - Arroyo Willow

Arroyo willow is the sole or dominant shrub or tree in the canopy with red willow, shining willow, sandbar willow, and box elder subdominant.
Observed Associated Species:
Red willow, shining willow, sandbar willow, Fremont cottonwood, Mexican elderberry, mugwort, rose, box elder, valley oak, Hinds walnut, Himalayan blackberry, California blackberry, Gooding's black willow, cherry plum, California wild grape, sharp and curly dock, willow-weed, and other under story grasses and herbs (see plant list).

BKW - Black Willow

Black willow is the sole dominant shrub or tree in the canopy with Hinds walnut and box elder subdominant.

Observed Associated Species:
Black willow, Hinds walnut, box elder, California wild grape, arroyo willow, Fremont cottonwood, and Mexican elderberry.

BM - Bulrush Marsh
Bulrushes are sole dominants in the herbaceous canopy.
Observed Associated Species:
Broadleaaf cattail, California bulrush, common three-square, common tule, narrowleaf cattail, and river cattail.

BOX - Box Elder
Box elder is the dominant tree in the canopy with Fremont cottonwood and Oregon ash the subdominants.
Observed Associated Species:
Fremont cottonwood, Oregon ash, Hinds walnut, arroyo willow, and Himalayan blackberry.

BS - Blackberry Scrub
Himalayan and or California blackberry are the dominant canopy cover. Subdominants may be any major tree or shrub species found in the area.
Observed Associated Species:
Box elder, valley oak, Hinds walnut, almond, Fremont cottonwood, Gooding's black willow, and arroyo willow.

BWL - Black Willow
Black willow is the dominant tree in the canopy; Fremont cottonwood, Mexican elderberry, box elder, Hind's walnut, and valley oak are sub dominants.
Observed Associated Species:
Gooding's black willow, Fremont cottonwood, Mexican elderberry, box elder, Hind's walnut, valley oak, arroyo willow, California wild grape, and mulefat.

CAS - California Sycamore
California sycamore is the dominant canopy cover tree with Fremont cottonwood the subdominant.
Observed Associated Species:
Fremont cottonwood, arroyo willow, box elder, valley oak, California wild grape, and Mexican elderberry.

FCW - Fremont Cottonwood
Fremont cottonwood is the dominant tree in the canopy with box elder and Hinds walnut the subdominant.
Observed Associated Species:
Box elder, English walnut, Hinds walnut, California wild grape, Himalayan blackberry, Oregon ash, arroyo willow, Gooding's black willow, edible fig, California pipevine, California manroot, and mugwort.

HWN - Hind's Walnut
Hind's walnut is the dominant tree in the canopy with box elder and valley oak the subdominants.
Observed Associated Species:
Box elder, valley oak, Mexican elderberry, Hinds walnut, arroyo willow, Fremont cottonwood, Mexican elderberry, mugwort, California pipevine, California manroot, California wild grape, California and Himalayan blackberry, and Oregon ash.

VO - Valley Oak
Valley oak is the dominant tree in the canopy. Subdominants are arroyo willow, almond, box elder, and Oregon ash.
Observed Associated Species:
Arroyo willow, almond, box elder, Oregon ash, California blackberry, Himalayan blackberry, Hoary Creek nettle, curly dock, pokeweed, and Mexican elderberry.

MUG - Mugwort
Mugwort is the dominant herb in the ground layer; cocklebur, mustard , curly doc, annual grasses, filaree, yellow star thistle, and old man of spring are present
Observed Associated Species:
Arroyo willow, black willow, California sycamore, Fremont cottonwood, Mexican elderberry, mulefat, valley oak, Oregon ash, Hind's walnut, cocklebur, mustard, curly doc, annual grasses, filaree, yellow star thistle, old man of spring, California and Himalayan blackberry, and almond.

VO - Valley Oak
Valley oak is the dominant tree in the canopy. Subdominants are arroyo willow, Hind's walnut, almond, box elder, and Oregon ash.
Observed Associated Species:
Arroyo willow, almond, box elder, Oregon ash, California blackberry, Himalayan blackberry, Hoary Creek nettle, curly dock, pokeweed, and Mexican elderberry.

NONVEGETATIVE CLASSIFICATIONS
G - Gravel (river wash)
NL - Polygon Not Listed (agriculture, urban, or other human use)
OW - Open Water

HOW TO OBTAIN MORE INFORMATION

The SRRM data may be obtained either electronically, or by mail. To obtain the data electronically, please email cwnelson@csuchico.edu or call Chuck Nelson (530) 898-5969.

* Provide your name, affiliation, address, telephone number, fax number, and

email address.
* Briefly describe how you will use the data.

To obtain the data by mail on CD-ROM, please do the following (there will be a service charge for developing and mailing the CD-ROM):

Send a written request containing the above information requested and a billing address to:

Chuck Nelson, Director
Geographical Information Center
California State University, Chico
Chico, CA 95929-0425
(530)898-5969
email: cwnelson@csuchico.edu

Department of Water Resources - Northern District
Sacramento River GIS
Version of Monday, April 30, 2001

The Sacramento River GIS was developed by DWR in cooperation with the Senate Bill 1086 Advisory Council. Its primary purpose is to assist with carrying out the objective of the Upper Feather River Fisheries and Riparian Habitat Management Plan, which is to reestablish a continuous riparian ecosystem along the Sacramento River between Keswick and Verona. It is intended to help with locally based decision-making, assisting both scientists and laypeople in understanding and analyzing land use and vegetation patters, flooding, erosion, and channel dynamics on the river.

The metadata for this GIS is nearly 50 pages in length, and is beyond the scope of that which can be printed here. However, an Adobe PDF format file containing this information is included on the GIS Project CD-ROM, created for this report. It can also be obtained by contacting the Project Contact:

Stacy Cepello - DWR Northern District
2440 Main Street
Red Bluff, CA 96080
(530) 529-7352
cepello@water.ca.gov

The Nature Conservancy Sacramento River Project
2-Dimensional Hydraulic Model Data

The model was created for TNC by Ayres Associates, and the results summarized in a report titled "2-Dimensional Hydraulic Modeling of the upper Sacramento River, River Miles 194-202, Glenn and Butte Counties, CA, December 7, 2001."

The model was run at a flow of 195,000 cfs, distributed accordingly: Sacramento River 170,000 cfs, Stony Creek 15,000 cfs and Big Chico Creek 10,000 cfs. All runs were done using data from the flood of January 1995, and land use/land cover was kept as 1995 "existing conditions."

For further information, contact:
Mike Roberts, Sub-Reach Project Manager
The Nature Conservancy, Sacramento River Project
500 Main Street Ste. B
Chico, CA 95928
(530) 897-6383
mike_roberts@tnc.org

Appendix G: List of Acronyms

A B C

ACOE: US Army Corp of Engineers
AFRP: Anadromous Fish Restoration Plan
BCC: Big Chico Creek
BCCWA: Big Chico Creek Watershed Alliance
CSUC: California State University, Chico

D E F

DPR: Department of Parks and Recreation
DWR: Department of Water Resources
EPA: Environmental Protection Agency
ERP: Ecosystem Restoration Plan
FEMA: Federal Emergency Management Agency

G H I J

GIS: Geographic Information System
GPS: Global Positioning System
IRZG: Inner River Zone Guideline

K L M

LSSs: Lateral Sediment Sources
MOA: Memorandum of Agreement

N O P

NPS: Non-Point Source Pollution
PRBO: Point Reyes Bird Observatory

Q R S

SB 1086: Senate Bill 1086
SRCA: Sacramento River Conservation Area
SRPT: Sacramento River Preservation Trust

T U V

TNC: The Nature Conservancy
USGS: United State Geological Survey
USFWS: United State Fish and Wildlife Service

W X Y Z